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THE UTILITY OF PLASTICS TO THE ENGINEER

by

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THE UTILITY OF PLASTICS TO THE ENGINEER

By W. A. COOK, B.Sc., M.I.E.E.

The Section Chairman Mr. Bennett, in introducing the Lecturer Mr. Cook, stated how pleased he was that the subject for the Lecture was Plastics, and he was very proud to occupy the chair with such a crowded audience, which was a sign that the subject of the Lecture was of great interest in the district, and on behalf of the Cornish Section of the Institution of Production Engineers he invited the Lecturer to present his paper.

1. INTRODUCTION.

The title of this paper may perhaps be considered misleading, because it will deal principally with one particular form of plastics —*i.e.* laminated materials. It would not however be unfair to assert in justification that this is the form likely to be of widest interest as an engineering material. Nevertheless, the paper would be incomplete without a few brief facts about plastics generally which will serve to relate laminated plastics with the many other forms now becoming available to industry.

2. PLASTICS GENERALLY.

2.1. Definition.

Finished plastics articles are of course not necessarily plastic (*i.e.* putty like) as the name might suggest, but are often hard and solid, and may remain so even when they are heated. Plastics are so called because at one stage in their production the materials are plastic and can therefore be pressed or moulded into shape. This plastic condition is produced by heating, often aided by pressure, and varies with different materials from something very close to a liquid to something of the consistency of putty. In some cases the finished plastics articles can be again softened by heating and remoulded, and the material is then termed " thermoplastic." In other cases it is not possible to soften the material again, and it is then described as " thermo-setting " or " heat-hardening."

The existence of a plastic stage during which moulding can take place is not of course peculiar to the materials generally known as " plastics " but is shared in some degree by metals, porcelain, glass and bitumen. There is some difference of opinion where to draw the dividing line between these other materials and plastics,

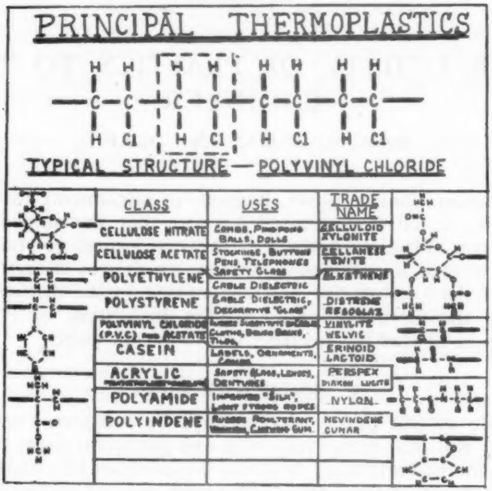

PRINCIPAL THERMOPLASTICS
TYPICAL STRUCTURE — POLYVINYL CHLORIDE
CLASS
USES
TRADE NAME
CELLULOSE NITRATE
BALLS, DOLLS
CELLULOID
XYLONITE
CELLULOSE ACETATE
STOCKINGS, BUTTONS
PENS, TELEPHONES
SAFETY GLASS
TENITE
POLYETHYLENE
CABLE DIELECTRIC
POLYSTYRENE
CABLE DIELECTRIC,
DISTRENE
POLYVINYL CHLORIDE (P.V.C) AND ACETATE
VINYLITE
WELVIC
CASEIN
LABELS, ORNAMENTS,
ERINOID
LACTOID
ACRYLIC
SAFETY GLASS, LENSES,
DENTURES
PERSPEX
DIAKON LUCITE
POLYAMIDE
IMPROVED "SILK",
NYLON
POLYINDENE
NEVINDENE
CUMAR

Fig. 1

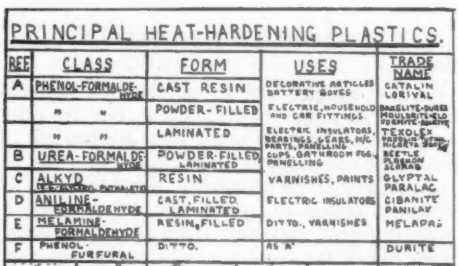

PRINCIPAL HEAT-HARDENING PLASTICS.
REF
CLASS
FORM
USES
TRADE NAME
A
PHENOL-FORMALDEHYDE
CAST RESIN
DECORATIVE ARTICLES
BATTERY BOXES
CATALIN
LORIVAL
" "
POWDER-FILLED
ELECTRIC, HOUSEHOLD AND CAR FITTINGS
" "
LAMINATED
ELECTRIC INSULATORS,
TEXOLEX
B
UREA-FORMALDEHYDE
POWDER-FILLED LAMINATED
PANELLING
BEETLE
C
ALKYD
RESIN
VARNISHES, PAINTS
GLYPTAL
PARALAC
D
ANILINE-FORMALDEHYDE
CAST, FILLED, LAMINATED
ELECTRIC INSULATORS
CIBANITE
E
MELAMINE-FORMALDEHYDE
RESIN, FILLED
DITTO., VARNISHES
F
PHENOL-FURFURAL
DITTO.
AS "A"
DURITE
THERMOPLASTIC STATE
METHOD OF LINKING
HEAT-HARDENED STATE

Fig. 2

but the term " plastics " is usually applied to a material which is produced synthetically—*i.e.* not produced by a process such as refinement of natural ores, but built up chemically from quite different materials of more simple chemical composition. Nevertheless some authorities include under the term resins which occur naturally, such as shellac, and even in some cases bitumen. Those plastics resembling natural resins in appearance are often described as synthetic resins.

2.2 Chemistry.

Figures 1 and 2 list the principal thermoplastic and thermosetting resins respectively and show the chemical structure of a typical molecule of each. A molecule is defined as the smallest particle of a substance which can exist independently and retain its chemical properties, and consists of a combination of atoms of one or more elements. The molecules of all plastics materials used until recently have consisted of strings or networks of carbon atoms to which are attached atoms of hydrogen, oxygen, sometimes nitrogen, and occasionally others. These molecules may contain tens of thousands of carbon atoms, and yet be far too small to be seen.

It is an interesting fact that the chemist can build up new plastics materials much as a builder does a house, first of all planning the structure needed to give the required properties, and then building up the atoms to his plan. In this way nylon was discovered and is now being used to produce strong light ropes for military purposes, as well as tooth-brush bristles, while it promises artificial silk stockings which are superior to and not just a poor imitation of the natural silk.

On account of the large proportion of carbon in such plastics, they will all char at temperatures varying from 100° to about 250°C. This effect can be retarded a little, but not drastically, by incorporating asbestos or some other non-inflammable material in the article. An entirely new class of plastics has recently been developed containing silicon (the basic element in sand) in place of part or all of the carbon, and promising therefore to resist higher temperatures.

A feature of all thermoplastic materials (Fig. 1) is a long string of atoms. The plasticity may be considered due to the relative ease with which these chains can move about amongst each other, much as a long line of people one behind the other can force its way through a crowd. The process of building up such chains from a series of identical groups in this manner is described as polymerization.

Thermosetting materials (Fig. 2) are initially thermoplastic : they have the characteristic chain structure and can be moulded. Application of sufficient heat causes the chains to cross-link to form a network, probably in three dimensions. The consequent infusibility may be compared with the difficulty a solid block of people would

have in forcing its way through a crowd. This process of conversion is known as curing, condensation, or sometimes bakelization. A change, similar but not identical to the curing effect of heat, may be produced by addition of a very small amount of acid, and this is the basis of cold-setting plastics cements.

Since plastics are generally compounds of carbon, hydrogen, oxygen and nitrogen, all elements which occur profusely in nature, it seems likely that abundant raw materials will be available, provided that economical means of processing them can be devised.

Small proportions of other ingredients termed plasticizers are often added to increase the fluidity during the moulding process or to add flexibility to the final product.

2.3. Fillers.

Most thermo-plastics articles contain little else besides the plastics material, although small quantities of other ingredients are often added to produce modified properties or reduced cost. The thermosetting resins, particularly phenol-formaldehyde, are not so often used neat. Phenol-formaldehyde resins are sometimes used alone for decorative and a few other purposes, but have comparatively low strength. Usually considerable proportions of filling material are included which may add strength, improve other properties, or reduce cost. The powder mouldings used for household accessories usually contain wood flour, but where special properties are needed as for shock-proof mouldings, slate dust, mica, asbestos, silica, fabric, etc., are used instead.

2.4. Grades.

It will be realized that the choice of filler and plasticizer will account for considerable variations between different grades of each type of plastics material, each of which in turn covers a class of materials varying in the length and complexity of the molecule and in other features. It is therefore important to realize that experience gained on one grade of a plastics material may not necessarily apply to others.

2.5. Laminated Materials.

Laminated plastics may be considered to have fillers consisting of sheets of paper, wood pulp, fabric, wood, or in fact of any fibrous material. This is however a somewhat misleading conception since the sheet material is at least an equal partner in the combination and it makes the principal contribution to several of the properties, *e.g.* tensile strength. It is preferable to consider laminated plastics as fibrous sheet bonded together with plastics. The proportion of plastics to fibrous material for most purposes varies from about 1 : 3 to 1 : 1. Laminated materials have a considerable advantage in strength and in certain other respects over other forms of plastics,

and they therefore find applications in the engineering industry for which the weaker and more brittle unfilled and powder-filled plastics are unsuited. The remainder of the paper will be concerned with laminated plastics, and will consider the manufacturing processes involved, the properties produced and the applications.

3. MANUFACTURE OF LAMINATED PLASTICS.

3.1. Basic Principles.

The manufacture of laminated plastics takes place in two main stages. The plastics material in its thermoplastic stage is first applied to the web of fibrous material. Heat then softens it and pressure forces it to impregnate the fibrous material more thoroughly and ensures intimate bonding of adjacent layers of material. This is done by one of several methods, namely :—

(*a*) Winding into tube.

(*b*) Pressing into flat sheet.

(*c*) Moulding into other forms.

The plastics material, if of the heat-hardening type, is converted to the final hard stage during this part of the process, possibly with the aid of a subsequent baking operation. For the moment attention will be directed to laminated plastics employing paper or woven fabric.

3.2. Application of Resin.

Figures 3 a and 3 b illustrate the most usual methods of applying the plastics material. A varnish produced by dissolving it in a suitable solvent is applied to the web which afterwards passes through a tunnel-type drying oven to remove the solvent and, in the case of heat-hardening resins, to confer a degree of cure. It is necessary to cure such resins as far as possible without destroying the

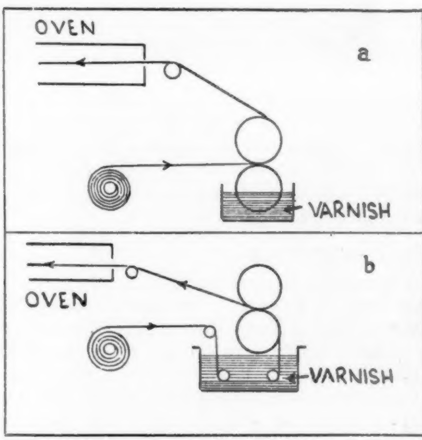


Fig. 3. Methods of Applying Resin to Fibrous Web.

plasticity before the final pressing operation, as the curing involves liberation of water which it is undesirable to entrap. In Fig. 3 a a coat is applied to one side of the web from the roller dipping in the varnish. The amount of the deposit is controlled by regulating the gap between this roller and the one above it. The web emerges from the oven with a dry resin surface and is reeled ready for the next stage. In Fig. 3 b the web dips into the varnish and so becomes coated both sides and saturated. The first method is more suitable for paper, which when wet with varnish either in this or the winding

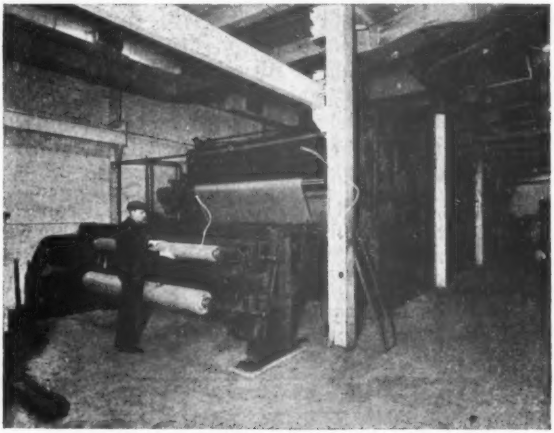


Fig. 4

process is often not strong enough to overcome the stiction between resin on the reverse side and the rollers over which it runs. The second method is applicable to fabric. Fig. 4 shows a machine for carrying out this process.

3.3. Tubular Winding.

Wound tubular articles principally employ a phenol-formaldehyde heat-hardening resin, and the following process is described in a manner applicable to this resin. The web of treated paper or fabric is wound under tension on to a mandrel corresponding to the required internal diameter in the manner shown in Fig. 5. The mandrel is driven between the three rollers B, at least the bottom two of which are heated, whilst the upper one applies mechanical pressure. The roller A serves to preheat the paper and remove any remnant of volatiles such as moisture. The temperature of the front

roller B and the duration of its contact with the web are controlled to bring the resin to a condition in which it will give sound adhesion as it passes on to the mandrel, without trapping volatiles such as the water produced by condensation. The wound material then passes into contact with the back roller B, which is maintained at a higher temperature, and which consolidates the material and commences the process of condensation, and in fact carries it to a fairly advanced stage. As condensation nears completion it takes place increasingly slowly, and a baking operation of several hours is necessary to complete the curing. The tension, pressure and heat in the winding process combine to produce a dense, strong, hard product. In this way the material is partially cured layer by layer as the product is built up, and the volatiles produced in condensation escape. Other processes entrap these to the detriment of the electrical properties. Detriment to the mechanical properties is more than made good by the greater pressure with other processes. Typical winding machines are shown in Fig. 6.

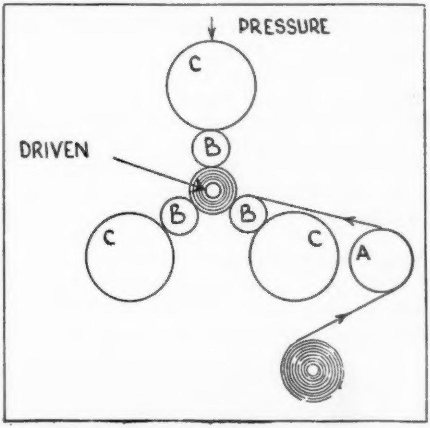


Fig. 5. Diagram of Winding Process.

The process first described applies also with small modifications to other types of plastics. With thermo-plastics the temperature control is less critical as the resin remains adhesive indefinitely if the temperature is sufficiently high, and as no products of condensation are liberated. In some cases the paper coating and impregnat-

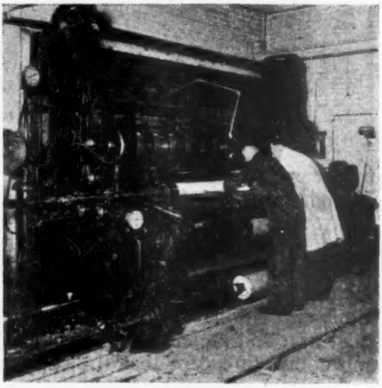


Fig. 6

ing process described in section 3.2 has been omitted and pulverized resin sprinkled on to the web of untreated paper on the winding machine just before it reaches the heated rollers. This process is only possible with resins which are sufficiently solid to be pulverized successfully, and has only met with limited success.

Material produced in this manner has no polished finish except on the inner surface which was in contact with the mandrel. After machining to the size and shape required, material for electrical and certain other purposes must always be given a substantial coat of varnish. For mechanical purposes, particularly when fabric is used, this may not be necessary, and where a glossy finish is needed it may be obtained by a polishing (lapping) operation.

3.4. Sheet Pressing.

Laminated sheet is produced by compressing together at a suitable temperature pieces of varnished paper or fabric stacked one above the other, normally in a hydraulic press with platens heated

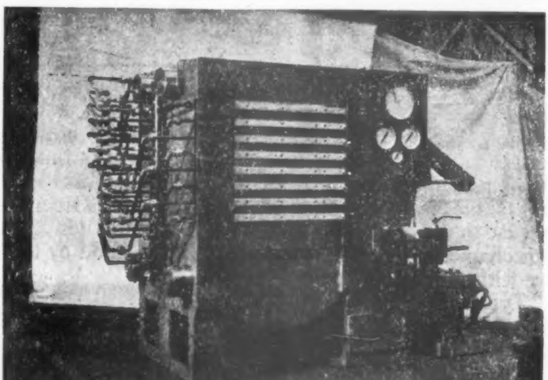


Fig. 7

by steam, gas or electricity. For speed of production a multi-daylight press as shown in Fig. 7 is used, and one thick sheet or many thin ones are formed in each daylight. The surfaces of the sheets are produced by inserting highly polished metal plates at appropriate positions in the stack. Sufficient resin oozes through the material and floods the surface to form the hard polished finish familar in laminated sheet without additional process. With sufficient heat and pressure the sheet emerges from the press fully cured, and complete except that the edges need trimming. The process, particularly with fabric, does not provide for high accuracy in the

thickness, which can only be adjusted by altering the number of pieces of paper or fabric. Where special accuracy is needed, the natural surface must be sacrificed and the sheet sanded down to size. Curved sheet can be produced in the same manner between suitably shaped plates.

For some purposes thin sheet is produced at a lower temperature so that it is not fully cured. It can then be bent when hot on formers to make simple shapes. For decorative laminated paper sheet the outer layer can be of thin wood veneer or of paper printed to give a very close resemblance to figured wood or any desired pattern.

3.5. The Effect of Laminations.

Before considering the manufacture of laminated mouldings, it is desirable to direct attention to the consequence of the laminated structure. The strength of laminated plastics, being provided largely by the paper or fabric, is governed by the direction of the laminations; forces which tend to break the fibres or threads are resisted much more strongly than forces which tend to make them slide upon each other. Thus tensile strength is greatest along the layers, shear strength greater across than between the layers, and compressive strength and electric strength are greatest at right angles to them (Fig. 8).

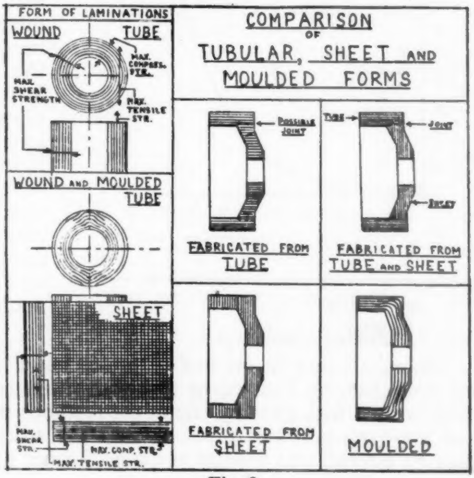


Fig. 8

There are many different grades of laminated plastics produced. Some split easily and others have a very great resistance to splitting. On the one hand are grades principally intended for electrical insulation, in which the layers of paper or fabric can be very distinctly seen when the material is cut. On the other hand are grades mainly applicable to mechanical use in which the paper or fabric is pressed together to such an extent and impregnated so thoroughly that layers can be seen only with difficulty.

The ratio between the strengths in the weaker or stronger directions varies with different grades of materials as follows :—

Tensile strength.—Laminated materials are never used with any substantial forces separating the layers by direct pull.

Compressive strength.—30-70%.

Shear strength.—4-20%, paper ; 30-80%, fabric. The much higher ratio with fabric naturally follows from the interlocking action between the threads in adjacent layers of fabric when they are pressed together, which is most pronounced with a coarse-weave material.

Electric strength.—15-40%.

Fig. 12. Moisture Absorption of Lam. Paper

These variations in strength places some limitations on the use of tubular and sheet material. In many cases these can be overcome by carefully choosing the more appropriate form and perhaps by suitably fabricating the article from both forms. In other cases a solution is the use of laminated mouldings in which the direction of laminations can be controlled to give strength where it is needed (Fig. 12).

3.6. Laminated Mouldings.

The most common method of producing a laminated moulding involves charging a moulding tool with sheets or pieces of paper or cloth treated with resin by one of the methods previously described, and applying heat and pressure until the article is cured. It can then be ejected, and usually needs no further operation other than removal of flashes or charging necks.

Laminated mouldings will be grouped as follows :—

1. Fully laminated mouldings in which the laminations have substantially the full extend of the article.
2. Semi-laminated mouldings in which the paper or fabric is in smaller pieces which still lie in the main parallel to each other.
3. Transfer mouldings in which the pieces of paper or fabric become further disintegrated and intertwined in the moulding process.

4. Pulp mouldings in which sheets of pulp are used giving a less distinctlye laminated form.

3.6.1. Methods of Moulding.

Before considering laminated mouldings specifically, the several methods of moulding available for plastics will be discussed.

(*a*) In compression moulding the tool is placed between the heated platens of a press and the charged cavity in the tool reduced in size until the material is fully consolidated and cured. The tool is of the flash type (Fig. 9 d) if excess material is allowed to escape from the sides of the cavity when the cavity has been reduced to the final size, and is of the positive type (Fig. 9 e) if no such escape is allowed. In the former case flashes have to be removed after extraction ; in the latter case great accuracy in charging is necessary to give the correct size. A flash tool is more simple to construct

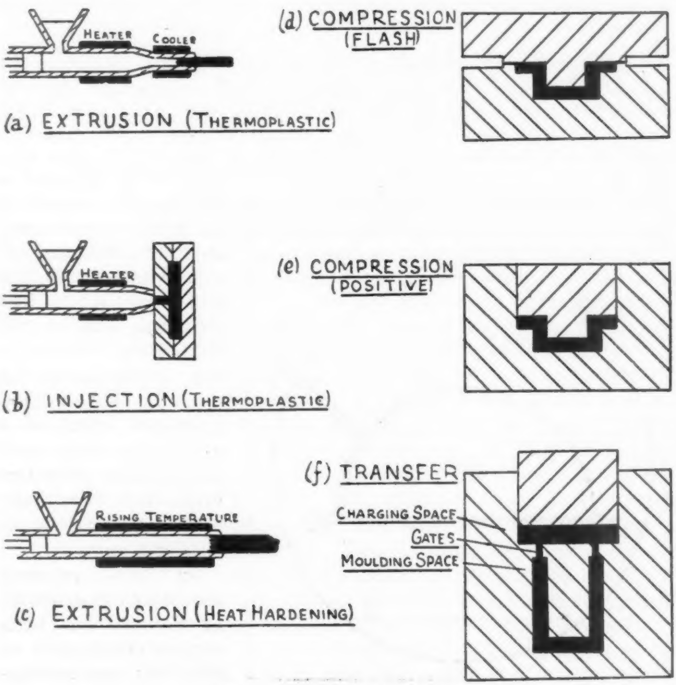


Fig. 9. Methods of Mouldings

but cannot be applied so frequently to laminated materials as to powders since the flash is more apt to prevent the mould closing. Where the depth of the tool is considerable sufficient heat may not be transmitted from the platens and the tool itself must then have heating ducts connected to a steam, gas or electricity supply.

(*b*) In injection moulding (Fig. 9 b) the charge is intermittently and progressively forced forward in a heated cylinder by a plunger. It emerges through a nozzle into the mould. This method is usually applied to thermo-plastics, and the mould is then kept cold.

(*c*) Extrusion moulding (Fig. 9 a), which is applied to rods and other uniform sections, closely resembles the injection process, but the moulding cavity is omitted and the material cools into the required form as it leaves the nozzle. With thermo-setting material an additional higher-temperature stage is incorporated beyond the nozzle to effect curing (Fig. 9 c). Neither injection nor extrusion processes have yet been developed far in connection with laminated materials.

(*d*) Transfer moulding (Fig. 9 f) in some respects resembles the injection process. The tool differs from a compression tool in having separate charging and moulding cavities, the latter being multiplied to increase production where necessary and possible. The moulding cavities are completely closed apart from gates into the charging cavity. A charge rather in excess of that required is placed in the latter and then forced by a plunger into the moulding cavity or cavities. The operation takes place in much the same way as compression moulding. The gates are then severed and the moulded articles and the excess material in the charging cavity ejected. This method gives the effect of a closed mould and simplified multiple production without demanding accuracy in charging.

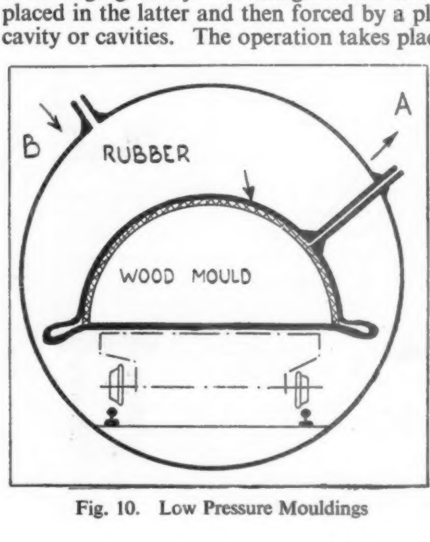


Fig. 10. Low Pressure Mouldings

(*c*) Low pressure moulding as illustrated in Fig. 10 has been successfully applied to synthetic resin laminated plywood, and to

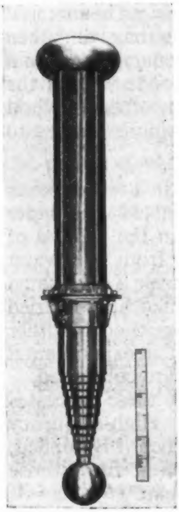
some extent to thin simple shapes of laminated fabric. The material is laid on a former in strips, enclosed in a rubber bag, and then placed in an autoclave oven. The rubber bag is evacuated and steam or other hot fluid at high pressure introduced outside it until the material is consolidated and cured. The limitations of this method are the pressure which can be applied and the simple shapes to which it is restricted.

(*f*) Pulp preformed moulding has been discussed in a recent paper presented to the I.P.I. The resin is applied in or mixed with paper fibres in the form in which they leave the beater in the process of paper manufacture. The treated fibre is drawn from the water with which it is diluted on to a wire gauze placed over a perforated mould by applying a vacuum inside it. The deposited fibre is dried in warm air and then pressed by the rubber bag method or other suitable means. The technique appears to be still in an experimental stage so far as articles having substantial strength are concerned.

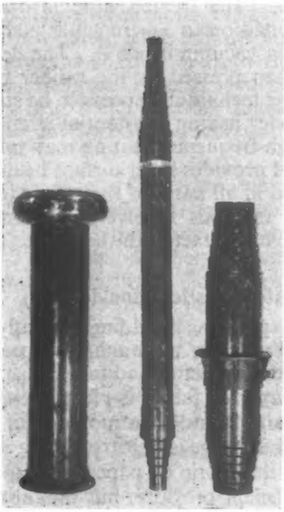
Infra-red and high-frequency heating may modify these processes in future. Infra-red provides local surface heating. High-frequency heating is developed in all parts of the article to which it is applied, whereas the usual methods involve slow conduction from those parts of the surface in contact with the source of heat.

3.6.2. Fully Laminated Plastics Mouldings.

Fully laminated plastics mouldings usually employ the compression moulding process, although low pressure moulding has been applied to wood laminates and in a few special cases to fabric. The impregnated paper or fabric is placed in the cavity of the tool in suitably shaped sheets and then moulded in the normal manner. The preshaping of the charge is not so exacting as might be supposed. Both the resin and the fabric or paper will flow moderately well in the mould with sufficient pressure, but the fabric and paper will be restricted by sudden constrictions in section and so not uniformly consolidated. Therefore successful moulding into long narrow passages is not possible although the difficulty can often be circumvented by altering the direction of pressing and so converting the long narrow passages to short wide ones. Outside such difficult cases a wide variety of shapes including some of considerable complication remain possible. This is best understood by an examination of typical examples (Figs. 17). The possible shapes of paper articles are more restricted than fabric because the paper cannot be stretched to the same degree as fabric in order to conform to the mould without the paper fracturing and losing much of its reinforcing effect. The method of charging and the form of mould must be carefully designed so that taut fibres occur in the direction

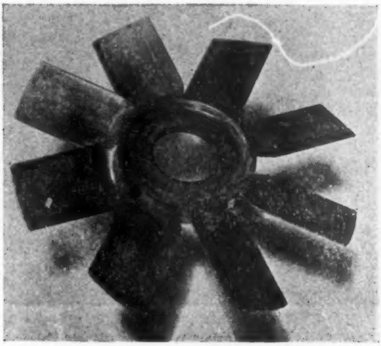


17 a. 400 kV Testing Transformer Bushing Wound Laminated Paper.

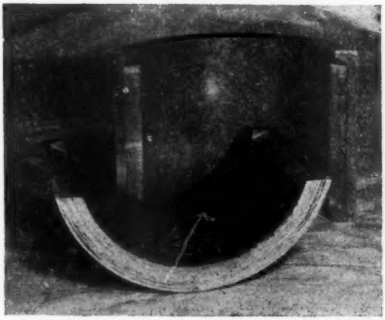


17 b. 400 kV Testing Transformer Bushing Components.

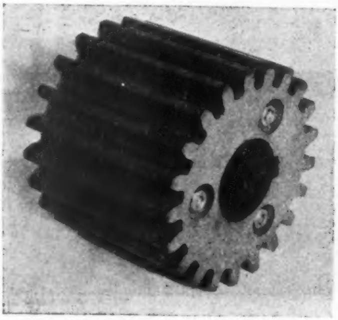
17 c. Aerial Mast Fairing for Aircraft. Moulded Laminated Fabric.



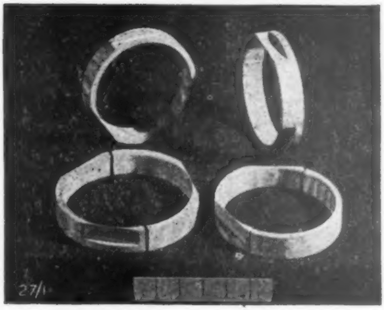
17 d. Engine Cooling Fan. Moulded Laminated Fabric.



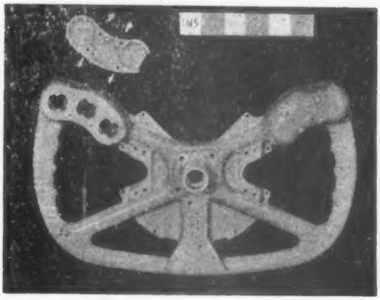
17 e. Rolling Mill Bearings Moulded Laminated Fabric.



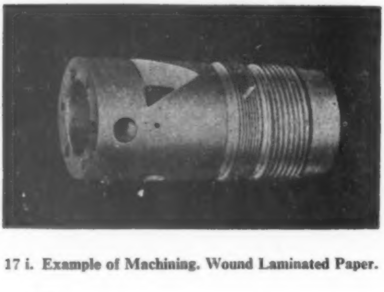
17 f. 9 in. Pinion. Sheet Laminated Fabric.



17 g. Anti-Chafing Rings. Wound Laminated Fabric.

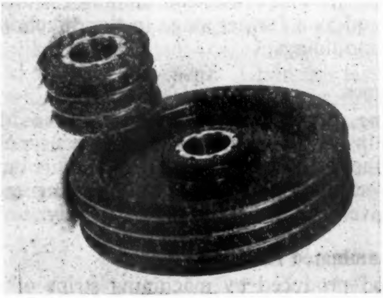


17 h. Aircraft Control Handle. Moulded Laminated Fabric.

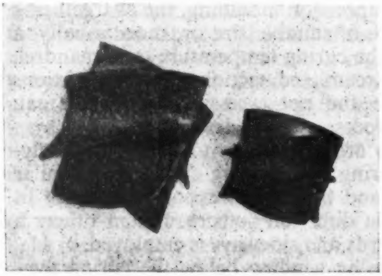


17 i. Example of Machining. Wound Laminated Paper.

17 j. Blow Gun Handle. Semi-Laminated Fabric Moulding.



17 k. Pulleys for V-Rope Drive. Semi-Laminated Fabric Moulding.



17 l. Meter Impellor. Semi-Laminated Fabric Moulding.

of maximum tensile stress wherever it occurs. Attention to this point has vital significance to the performance of laminated mouldings, which so made are stronger than any other form of plastics moulding.

3.6.3. Semi-Laminated Plastics Mouldings.

The limitations to shape and size can be widened and a cheaper moulding produced by what will be described as the semi-laminated moulding. This involves some reduction in strength in the optimum directions, but gives greater uniformity in strength in all directions and so may be more appropriate to the requirements of some articles although not to others.

3.6.4. Transfer Laminated Mouldings.

Transfer-laminated mouldings are perhaps not strictly entitled to the adjective " Laminated " because the passage of the paper or fabric through the gates from the charging to the moulding cavities in the transfer tool causes considerable disintegration. They may be considered as a further stage in the direction taken by the semi-laminated mouldings.

3.6.5. Other Types.

Pulp moulding, produced by compression-moulding layers of impregnated pulp or by other processes such as pulp-preforming, share many of the features of laminated materials but have not the advantages of orientation of the fibres. String mouldings have application to give strength in one direction only.

3.7. Moulded Laminated Rods and Tubes.

Laminated rod produced by machining strips of sheet material involves some difficulty due to the different resistance offered to the cutting tool when it cuts across and along the layers, particularly noticeable when the grade has obvious laminations. A preferable form of rod is produced by compression moulding, the charge being sometimes in the form of strips of suitable size or, more usually, a small-bore tube wound below the curing temperature on a mandrel.

Tubes of uniform oval or streamlined section, or other sections having a continuous curvature and not excessively elongated can be produced by the winding process already described.

Square or rectangular tubes are wound on to correspondingly-shaped mandrels below the curing temperature either on a similar winding machine or by hand and then compression moulded. In some cases pressure in a single direction suffices, but in others a press exerting pressure downwards and sideways is employed.

Circular tubes are also made by winding below the curing temperature and then moulding. This allows greater pressure to be

applied than in the winding process but involves distortion of the layers as shown in Fig. 8, which is a serious disadvantage electrically and weakens the tube mechanically against forces in certain positions. The properties usually achieved by the high pressure can be obtained by the winding process alone when resin and paper or fabric are suitably chosen.

4. GRADES OF LAMINATED PLASTICS

Some indication has already been given that a wide range of properties is obtainable from laminated plastics by controlled variations of the laminating material, the resin and the manufacturing method. Further consideration will now be given to this point.

4.1. Effect of Laminating Material.

4.1.1. Paper.

The papers used include kraft (wood-sulphate), wood-sulphite, manilla, alpha cellulose and cotton. The properties of the final laminated product depend upon the type of paper used and upon the degree to which it is beaten—*i.e.* whether it is hard and non-porous or soft and highly absorbent. Upon this last factor depends the degree to which resin penetrates and impregnates the paper, which has an important bearing on properties discussed later. The strength of the final product is governed largely by the tensile and tearing strength of the paper, and upon the degree to which the paper ages or deteriorates during the processing. Chemical neutrality of the paper is essential to avoid ageing and to obtain good electrical properties.

4.1.2. Fabric.

Laminated fabric similarly depends upon the material chosen for the thread, whether American cotton, Egyptian cotton, linen, jute, hemp, silk, artificial silk, glass fibre or asbestos. These vary considerably in strength and absorbency with consequent effects upon the laminated fabric. The first three materials are most commonly used. Asbestos is used to obtain higher burning and carbonization temperatures and to make laminated components for chemical plant. The working temperature cannot however be substantially increased so long as carbon-based plastics resins are used and is normally modified from about 150°C. intermittent with paper or fabric to 200°C. with asbestos.

The properties of the product can be further varied by the type of weave employed in making the cloth. Cotton fabrics vary from light cambric to heavy duck cloths ; generally plain square weaves are used, but moleskin, corded fabric and other special weaves have applications. Laminated plastics manufactured from woven fabric

are rarely so strong in tension as those made from paper. This is due to the crimp in the threads where hey cross over one another. When a laminated fabric plastics is stressed, the full reinforcing effect of the cloth is not secured until the material has become sufficiently elongated to pull the longitudinal threads as straight as the interlocking construction of the cloth will permit. With ordinary square weaves considerable elongation is required and usually before this can be effected the synthetic resin in which the fabric is embedded will fracture. Considerable thought is given to the design of fabrics intended for laminated plastics, in order that this effect may be minimized. In order to produce really high tensile sheets, special cord fabrics have been manufactured in which the threads in one direction are held perfectly straight without crimping. These threads take the form of cords held together by much lighter cross threads. The resulting plastic has exceptionally high tensile strength in the direction in which the cords run, but a lower tensile strength in a direction normal to the cords.

The relative advantages of laminated paper and fabric are :—

Advantages of paper.	**Advantages of fabric.**
Greater strength under steadily applied load.	Greater strength under impact.
More rigid.	Greater resistance to splitting between laminations.
Better electrical insulation.	Better wearing properties under rubbing action.
Cheaper.	Absorption of moisture does not reduce the strength or wearing properties.
Produced to accurate limits by simpler machining operations.	More readily moulded.

4.2. Effect of Resin.

The majority of laminated plastics are made with phenol-formaldehyde type resin. This type includes resins synthesized from cresylic acid which usually contribute high dielectric strength, and resins synthesized from phenol which contribute mechanical strength. Apart from this the properties imparted by the resin and the degree to which it penetrates may be varied due to minor differences in the raw materials or to details of the manufacturing process, such as the choice of catalyst required to assist the chemical action.

Phenol-furfural resins are used in U.S.A. for laminated products with similar results to those with phenol-formaldehyde resins. Furfural is obtained from oat husks or corn-cobs.

Urea-formaldehyde resins are used for decorative sheet owing to the ease with which light colours can be produced, but are not quite so good electrically as phenol-formaldehyde resins, although it is claimed that they do not track or treemark under electrical discharge. Whether this claim implies any substantial difference, particularly in

laminated materials, is open to doubt. At any rate urea resins have not hitherto offered sufficient inducement to be used in laminates except for special purposes.

Aniline-formaldehyde resins are condensed or cured only in the presence of other chemicals and not by heat alone. They have only recently promised commercial importance. They are not soluble in commercial solvents, but have been incorporated in paper during its manufacture and laminated materials thence produced successfully. These have been applied for such items as the operating rods of switchgear but have not offered advantages over phenol-formaldehyde laminates for general electrical or mechanical purposes.

Polystyrene-laminated paper offers greatly improved electrical properties, but the operating temperature is limited by the fact that the resin is thermo-plastic at about 90°C.

Other resins offer a field for future exploration.

4.3. Effect of Degree of Impregnation.

Livingstone Smith has recently given some interesting evidence on this point collected by the National Physical Laboratory in respect of laminated paper. The first conclusion from this and other investigations is that a given paper develops the best mechanical properties when all the voids in the paper are completely filled with resin. The smaller the resin content the greater the pressure necessary to effect this condition. Fig. 11 illustrates the variation of tensile and compressive strengths with resin content for a particular paper-grade and pressure. The maximum in the tensile curve corresponds to complete impregnation. The corresponding resin content depends on the paper. There is evidence that this maximum will be greatest when full impregnation is achieved with the minimum proportion of resin. The compression strength

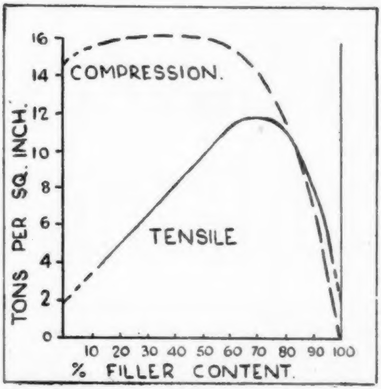


Fig. 11. **Tensile &** Compressive Strength of Laminated Paper.

and shear strength between layers (which follows a similar curve to compression) reaches its highest value with full impregnation and retains it with excess resin. The particular full-impregnation resin

contents giving the highest compressive and shear strength are open to some doubt. Practical results and consideration of the factors involved suggest that maximum strengths will be achieved when the resin proportion is great enough to stiffen the fibres sufficiently but not so great as to prevent adequate reinforcement by the fibres.

Moisture absorption is shown by Fig. 12 to rise continually with resin content. This might be expected as the resin is the moisture-resisting component.

The electrical strength of laminated paper, particularly at high temperatures, is supplied mainly by the paper, and the function of the resin in this case is to bind the paper together into a mechanically strong body, and to prevent the electrical properties of the paper being impaired by moisture, voids, and other deteriorating factors. Where high electric strength at high temperature is required, it is therefore necessary to use layers of

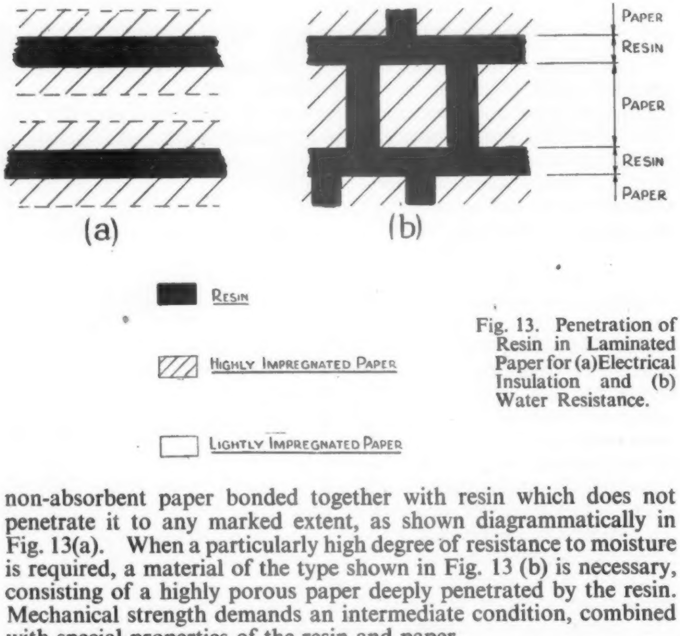


Fig. 13. Penetration of Resin in Laminated Paper for (a) Electrical Insulation and (b) Water Resistance.

non-absorbent paper bonded together with resin which does not penetrate it to any marked extent, as shown diagrammatically in Fig. 13(a). When a particularly high degree of resistance to moisture is required, a material of the type shown in Fig. 13 (b) is necessary, consisting of a highly porous paper deeply penetrated by the resin. Mechanical strength demands an intermediate condition, combined with special properties of the resin and paper.

It is of importance to realize that the features of materials and process which cause a grade of laminated paper to excel in one property may be widely different from those leading to excellence

in some other respect, and the requirements may in fact conflict. The most suitable grade for a particular purpose may therefore have to sacrifice non-essential requirements to gain the properties most necessary. For this reason it is of the utmost importance that the manufacturer should be made fully acquainted with the duties to be performed, so that he may offer the grade of material most likely to give the best results. It is equally important to avoid the specification of needless properties ; the over-emphasis of some attractive, but not fundamentally necessary property may quite easily force the maker to supply material less suitable for the principal requirements than it need otherwise be.

Fabric is again best fully impregnated, but the properties are complicated by effect of thread size and coarseness and type of weave. Some consideration has been given to this earlier in the paper.

5. PROPERTIES OF LAMINATED PLASTICS

A general picture of the properties of laminated plastics in relation to plastics of other types is given in Fig. 14. Tapering peaks indicate ranges of variation. The figure should not be regarded too critically as it has not been possible to take into consideration all the numerous special variants of the materials indicated. It will be seen that the mechanical properties of laminated phenolic materials are outstanding and only equalled by plastics in thread form (such as nylon) which serve entirely different purposes. The moisture absorption of laminated paper and fabric is naturally higher, but can still be reduced to small proportions.

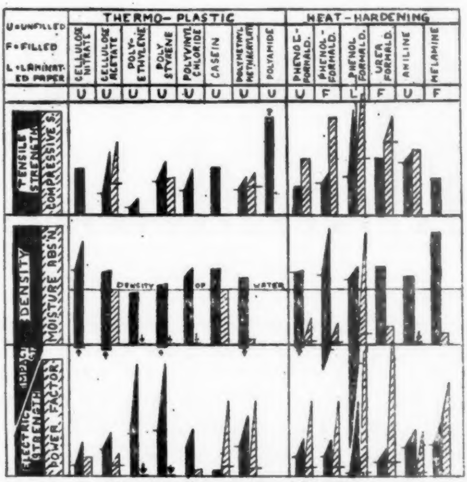


Fig. 14. Properties of Plastics.

Fig. 15 compares the properties of representative commercial

grades of laminated paper and fabric. The paper tubes and sheet grades include from left to right a highly impregnated material having high resistance to moisture and good electrical properties (ZA, XA), which is of little interest to the mechanical engineer ; another highly impregnated tougher paper having outstanding mechanical strength (ZT, XT) and a more distinctly laminated material employing non-porous paper having outstanding electrical properties (ZC, XC). In each case the sheet material is mechanically stronger than the corresponding tube material due to the greater pressure possible in manufacture and consequently more complete impregnation. The electrical properties are poorer due to failure of the sheet process to remove water produced in curing, and due to the more complete impregnation. Fabric sheet is again stronger than tube. There is some drop in strength with the coarser weave except in respect of the shear strength between layers, where the interlocking action between the threads in adjacent layers takes effect. Corded materials are not included in the figure. They generally give high strengths along the cord and lower strength at right angles. Fully laminated mouldings closely resemble sheets in properties, but usually do not quite equal them probably due to the fact that a flat test specimen made in a closed mould will have the threads less stretched than in ordinary sheet. In a moulding where similar stretching occurs the strength is likely to correspond to that of sheet. The strength of a commercial moulding will of course vary from point to point depending upon the tautness or otherwise of the threads.

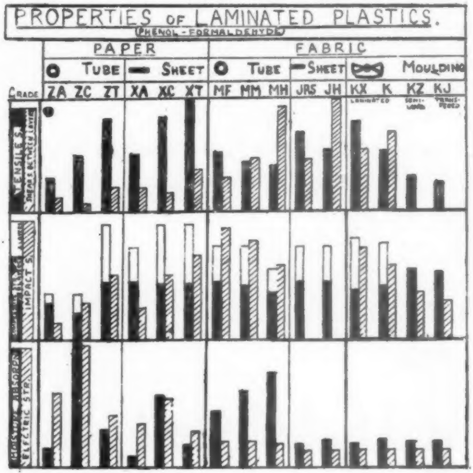


Fig. 15.

5.1. Mechanical Strength.

Laminated paper boards have been made having a tensile strength of 40,000 lbs/sq. in. in one direction, but commercial varieties normally reach only about 25,000 lbs/sq. in. This is remarkably high for a material of such low density. Fig. 16 makes a comparison between the specific strengths of a number of common materials. The specific strength is the length of suspended rod of uniform section which will just break under its own weight. These lengths give a direct comparison between the ultimate fracture loads on rods of equal lengths and weights. Although the laminated plastics line is calculated from the 40,000 lbs/sq. in. figure, it would still compare favourably if reduced to 9 miles, corresponding to the "commercial" figure of 25,000 lbs/sq. in.

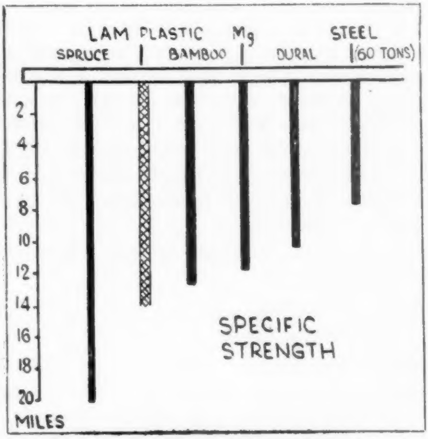


Fig. 16. Specific Strengths of Materials.

Compressive strength varies from 25 to 50,000 lbs/sq. in. on commercial grades of paper and fabric.

Shear strength across layers approximates to the tensile strength.

Shear strength between layers is from 400 to 8,000 lbs/sq. in.

Cross-breaking strength or modulus of rupture is usually some 50% greater than the tensile strength whereas with metals it is closely similar. (The cross-breaking strength is the calculated maximum stress in the extreme fibre of a beam when the customary bending formulae are assumed.) Laminated plastics therefore show a greater advantage in bending than in straight tension. Moreover if the increase in section of a rectangular beam, possible due to the lighter density compared with steel, were wholly absorbed by an increase in depth, the total strength for the same weight would be increased as the cube of the density and for commercial laminates would be over 40 times that of a steel bar of equal weight. Alternatively, equal strength could be obtained by a bar 75% deeper and 30% of the weight. The deflection would be reduced to equality if the bar were 2½ times as deep and 40% of the weight of the steel.

Impact strength depends on very indefinite properties of the material, and has very little meaning except for comparison with similar materials. Experience however shows considerable resistance to impact particularly with fabric materials.

Brinell hardness is low compared with most metals—*i.e.* the indentation under a steady load is large. A figure of 30 to 40 with 2 mm. ball and 40 kg. load is usual. Shore schleroscope tests give a figure of 65 to 75 which is comparable with the figure given by case-hardened mild-steel having a Brinell hardness of 600. The effect of an impact blow on the surface of laminated plastics is much less than on metals. Blows delivered by dropping a 7/8″ steel ball 100 times from a height of 6 ft. (energy 0·6 ft. lbs) on to one point on the surface gave the following comparison :—

Natural surface of laminated-fabric moulding	No damage. Point of impact could not be detected.
Laminated-fabric sheet on cut edge, polished	Ditto.
Laminated-fabric sheet on cut edge, unpolished	Just marked.
Mild steel plate	3/8″ indentation.
Duralumin plate	3/8″ indentation.

Young's modulus varies from 700,000 to 2,000,000 lbs per square inch (reaching the upper limit in paper or in one direction of corded fabric materials) compared with 30,000,000 for steel—*i.e.* the strain is 15 to 40 times as great. This feature has several interesting effects :—

(1) The material can deflect considerably before excessive stresses arise in it. The safe deflection is of the order of 5 times that of steel in tension or bending and 10 times in compression. There are many applications where this greater movement may prevent excessive stresses arising, and laminated plastics then have a clear advantage.

(2) The relatively large extension under load prevents laminated plastics sharing the load in a composite metal-plastics structure, so that metal cannot be used to reinforce laminated plastics unless the metal itself is of sufficient section to take the load alone. Thus in a composite cylinder comprising steel outside and a liner of laminated material inside, under internal pressure the liner will offer no mechanical aid to the steel. Nevertheless, it may have considerable value as, for example, a non-corrosive, low friction or insulating liner.

(3) For the same reason, much greater interference fits are tolerable between metal and laminated material than between metal and metal. The very close machining accuracy necessary for a metal-to-metal fit is therefore often quite unnecessary with a plastics-to-metal fit.

(4) In the case of the steel tube with plastics liner the liner will give sufficiently to transfer the bulk of the stress to the steel despite a poor fit. A metal liner on the contrary might fracture unless a very close fit. Similarly a laminated part attached to a steel component capable of taking the full stresses is never likely to fracture as would, for example, a brass sleeve outside a steel tube under internal pressure.

There are, of course, cases where this extensibility is detrimental, but these will be sufficiently obvious to need no mention. One man's poison is another man's meat, and as with many other materials what is unsuitable for one design may be ideal for another.

The stress-strain curve for laminated plastics shows a slight continuous drop throughout its range, but little or no yield point comparable with that of metals until the breaking stress is almost reached. After the application of a load approaching the breaking point, recovery of dimensions will be slow and never complete, but no serious damage will result. Thus, although overloads may necessitate replacement, definite failure is comparatively unlikely.

Various investigations have been made upon the effect of prolonged steady stresses and fatigue on laminated plastics, including those recorded by Livingstone Smith, and these show a diminution of strength under prolonged loading or rapidly repeated loading. The results appear far from complete and are inconclusive in their relation to practical conditions. There seems no doubt of these phenomenon when the stresses are relatively close to the ultimate, but under such conditions metals would often yield. The author's experience is that constant or occasionally varying loads with a factor of safety of 5 causes no trouble in practice but that rather more is desirable when frequent changes in load are involved.

The mechanical properties usually become slightly better when the material is damp. They improve gradually as the temperature falls down to at least —40°C., and suffer a similar reduction at higher temperatures.

5.2. Electrical Properties.

It was the outstanding electrical properties which commenced the development of laminated plastics, then known as bakelized-paper. While there are better electrical insulators than laminated-paper, there are none which have at the same time such high mechanical strength and which can be made so accurately and therefore compactly. All grades of laminated plastics are electrical insulators but only those employing paper are really efficient. Fabric materials can be used for low voltages when strength is more important than minimum thickness. Special purification of the fabric and selection of fabric and resin can give improved electrical

properties at the expense of some of the usual advantages of laminated fabric, but there are not many cases except in the moulded form where fabric offers any advantage over paper for electrical insulators. The electric strength falls with rise of temperature and is lower for longer periods of application. These effects are much reduced when a low-loss resin such as polystyrene is substituted for phenol-formaldehyde.

5.3. Resistance to Chemicals.

Phenol-formaldehyde resin offers very considerable resistance to chemical attack, and when combined with asbestos in laminated asbestos provides a material having complete resistance to most organic and inorganic acids, all usual solvents, and to weak alkalis. Paper and fabric are themselves attacked by the acids but grades of laminated paper and fabric having a sufficient resin content to protect them are resistant to a considerable variety of acids and other chemicals. These include organic acids, weak mineral acids except nitric, all common solvents, and a large number of other chemicals including, for instance, chlorine. In particular, water with all its common impurities has no effect either as a result of direct chemical action or electrolytic effects. Corrosion is thus eliminated.

5.4. Wear and Friction.

Laminated-fabric has considerable resistance to wear and a low co-efficient of friction towards metals, under many circumstances lower than special bearing metals, either with or without lubricants. The importance of these properties in the application of laminated-fabric to bearings will be discussed in section 7.5.

5.5. Gas and Liquid Tightness.

Most sheet and moulded laminated materials are impervious even at high pressures to gases and liquids such as water, oil and chemicals which do not actually attack them. Laminated-paper tubes of the highly-impregnated varieties are also impervious, and laminated-fabric can be rendered so by special treatment. The better electrical varieties of paper tube are liable to penetration of gas or liquid, which on release of pressure tends to raise surface blisters in the attempt of the absorbed gas to escape. Suitably selected grades of tube will, however, reliably hold high pressures.

5.6. Weight.

The usual density of laminated paper and fabric approximates to 1/20 lb. per cu. in. with a small variation between different grades.

A comparison with common materials is given below :—

	Density	Relative density
Laminated paper and fabric ...	·05 lb./cu. in.	1
Water	·036	·72
Steel	·28	5·6
Brass	·30	6·0
Aluminium	·094	1·9
Wood	·013-·045	·26-·9

6. FABRICATION, MACHINING AND FINISHING.

6.1. Machining.

The machining technique employed upon metals may not, without modification, always yield satisfactory—or at any rate not the most satisfactory—results on laminated plastics. Nevertheless, laminated plastics can be simply and successfully machined by appropriate methods. A few notes upon these will no doubt be of interest as an indication of the ways in which it is possible to avoid damage and obtain the best results from laminated plastics materials. Attention must be given to the following points :—

(1) The materials are laminated. The stress necessary to split them between the layers of paper or fabric is less than that required to fracture them across the layers. If machining properties are of first importance, it is best to choose a material in which the laminated effect is least clearly defined. This is particularly necessary if the machining operations are to include the cutting of screw threads, which rely for strength upon cohesion between the layers. The operations of sawing, drilling, lapping and turning present little difficulty with any grades, but screwing, whilst possible with most grades of fabric material, can only be performed successfully with certain grades of paper material.

(2) High temperatures produced in machining may cause burning, distortion or delamination, and must be avoided. In the case of phenol-formaldehyde type plastics (*i.e.* most laminated plastics now on the market) scorching commences at 150 to 250°C., but the temperature may be lower or higher in the case of other types. Burning is an indication that excessive cuts are being attempted or that the tool is blunt.

(3) The dust produced has a clogging effect upon tools, particularly lanishing discs, saws and drills, and these must be cleaned or renewed with sufficient frequency. Where a large amount of machining has to be done, dust extraction plant is necessary.

(4). Cooling liquids may be absorbed by the materials to a small degree, to the possible detriment of some of their properties, par-

ticularly electrical insulation. This absorption will also make it extremely difficult to apply any surface varnish afterwards. In general, therefore, cooling liquids should be avoided, and the material machined dry.

(5) If laminated plastics are machined with tools previously used for metal, particles of metal may become embedded in the plastics material to the detriment particularly of its electrical properties. It is therefore essential to ensure that tools are completely clean and if possible to use them exclusively for plastics.

(6) It is essential always to have clean cuts and never to rip the material away. It follows that light cuts with sharp clean tools should be the rule. Cemented carbide tools are an advantage.

(7) The material has a tendency to close in upon the tool. Drilled holes will be slightly smaller than the drill. To counteract a similar closing effect the cutting edge of a tool such as a saw or milling cutter should be wider than the part behind it. With a circular saw it is simplest to have the tool projecting above the table by the minimum amount necessary and in the case of the larger tubes to cut through the wall only and rotate the tube rather than to attempt to cut the full diameter at once.

(8) When drilling, a slow feed is desirable particularly when breaking through, but it is better where possible to drill into a backing piece.

6.2. Finishing.

Laminated mouldings and sheets have an excellent finish as they leave the tool or press and no surface finishing is necessary. Laminated tube leaves the winding machines and ovens with a rough non-resinous surface on the outside and ends, and on the inside a finish similar to the moulded finish but lightly scored unless specially selected mandrels have been used. It is therefore essential to machine the outside by turning or sanding, and for a number of purposes the inside may also have to be machined.

Laminated paper tube is supplied varnished all over as a protection against moisture and dirt, except in the case of the specially hard grades which are sometimes used unvarnished. There is less need to varnish laminated fabric tube because its mechanical properties are never seriously affected by moisture ; varnish is only used for electrical applications and to improve appearance. Polishing is often a suitable alternative.

6.3. Fabricating.

Many articles can be built up from pieces of tubes, sheets and mouldings jointed to each other or to metal parts. Synthetic-resin baking cement or, where baking is not convenient, synthetic-resin

acid-cured cement is most satisfactory for this purpose, and the best results are obtained when the joint is held under pressure during the operation. In sleeve joints this condition is provided by an interference fit (up to about 0·005″ per in.). Sleeve joints can have a shear strength of the order of 300 lbs/sq. in. of contact area, which is comparable with the shear strength between the layers of electrical grades of laminated paper, though substantially lower than that of fabric or the better mechanical grades of paper. Butt joints are weaker, but for some purposes quite effective.

Such joints can be made liquid or gas tight for pressures of the order of 10 lbs/sq. in., and in some cases for more than this. A ball float $5\frac{1}{2}''$ diameter made by jointing two hemispherical mouldings, for example, has been made to withstand a routine test pressure of 225 lbs. per sq. in. applied externally.

7. TYPICAL APPLICATIONS OF LAMINATED PLASTICS.

The process of manufacture and the properties of laminated plastics have been considered at some length and it may appear that too little space has been left to allow due attention to be given to the question of applications. Suggestions for applications must, however, in the main come from the user, who is more familiar than the author with the problems to be met. With this in view, some pains have been taken to present the characteristics of laminated plastics as clearly and fairly as possible. From this basis, applications will no doubt suggest themselves.

Some uses to which the materials have already been put and which are being developed and promise success will be mentioned, but no attempt will be made here to forecast further avenues of use. These applications will be grouped according to the main property which is called into service.

7.1. For Electrical Insulation.

Laminated paper is one of the best and most important forms of solid insulation, and it was put to this use for some 20 to 30 years before any notable mechanical applications were considered. It remains one of the principal materials used for rigid insulators in high-voltage switchgear transformers and other electrical equipment. Its only serious competitor in this field is porcelain which offers cheapness of material, complete water resistance, and complete non-inflammability against the much greater strength, accuracy of manufacture and adaptability of design of laminated paper. For outdoor use laminated plastics insulators are usually protected by porcelain covers owing to the fact that they are liable to carbonize if any sparking occurs over the surface when wet, an almost inevitable event with any high voltage insulator under outdoor weather conditions.

Often the use for a mechanical purpose of a material which is at the same time an electrical insulator dispenses with the need to provide separate insulation for a metal part. Cams for operation of contacts, gear transmission between live and earthed parts are examples. The insulation property also obviates the possibility of damage due to electrolytic action which is often liable to occur with metal parts operating damp or in water.

7.2. For Finish.

Decorative panelling of laminated plastics has already been used extensively. Thin laminated sheet, backed up with plywood, is used for the manufacture of furniture and for decorative wall panels in public buildings, hotels and on board ships. The laminated sheet may possess an imitation wood grain or be self-coloured. Phenolic laminates are used for dark colours. Light pastel shades demand the use of urea resins. These materials are much less readily stained than wood and retain their polished appearance indefinitely. One example is the panelling in the state-room of the Queen Mary; table tops and bar counters provide others. Tables and counters made from this material are unaffected by split liquids and cannot easily be damaged by live cigarette stubs.

The high finish, apart from its attractiveness, serves a definite purpose in industry for such applications as pump parts since the polished low-friction surface of laminated plastics which would be extremely difficult and expensive to obtain on metal castings. This leads to an improvement in efficiency. Other examples are cylinders and other parts for hydraulic apparatus and pneumatic apparatus.

7.3. For Corrosion Resistance.

Corrosion resistance is very attractive for parts operating in water, chemicals, or dampness, since the need for this property has often enforced the use of special alloys which are often both expensive and difficult to apply. The complete elimination of rusting and other forms of oxidation without the need for regular painting is a further advantage of laminated materials.

The high resistance to chemical action renders the material suitable for many machine parts which are required to come into contact with chemicals. Acid pumps, pipes, valves, tanks, etc., are in wide use.

7.4. For Low Friction Wear.

In order to employ bearings which take advantage of the low coefficient of friction and low rate of wear of suitable grades of laminated fabric, it is necessary to ensure removal of the frictional heat without the temperature rising above 175-225°F. The low thermal conductivity of the material allows little of the heat to escape

through the body of the bearing and the bulk of it must be removed through the shaft or by a cooling fluid, the most effective being water. Lubrication as such is not important except in special cases. It follows that ideal applications are those where the bearing operates in water as in hydraulic pumps and other machinery and the stern shaft bearings of ships. Laminated fabric is being used extensively for rolling mill bearings under loads up to 4,000 lbs./sq. in. and successful test results have been obtained up to 6,000 lbs./sq. in. The advantages over metal bearings for rolling mills are longer life, lower power consumption, absence of corrosion, and resilience which stands shocks and gives accommodation to slight distortion or mal-alignment of the roll necks and allows foreign particles to embed themselves instead of scoring the necks. Fig. 17 includes a group of rolling mill bearings.

The material is not limited to use with water cooling and may, under suitable circumstances, be used with oil or even dry. The incorporation of colloidal graphite or other materials in the laminated fabric is sometimes an advantage.

Other applications which make use of the resistance to wear are found in hydraulic cylinders and packing rings, and section box covers and doctors used in paper-making.

7.5. For Resilience.

Many applications occur where the use of laminated plastics for mechanical parts or their interposition between metal parts avoids vibration and the consequent noise, shattering and hammering action. They have been used as anti-chafing and anti-fretting rings for aircraft in large quantities. The high resistance to surface impact has been mentioned. It suggests the use of the material for cams. Laminated plastics gear wheels eliminate noise and in a number of cases give better wear.

7.6. For Lightness.

These properties combined with lightness are appropriate to numerous applications. Many components of aircraft have been made in laminated plastics. These have in fact been the most important war time use of the material. Fuselages in laminated wood and fabric have been made by low-pressure methods. Aerial masts have proved stronger in service than metal masts, probably due to greater resilience and the use of a thicker and more rigid wall made possible by the lighter weight. Insulation problems have also been simplified. Such components as control wheels, pilots' seats, parts of hydraulic mechanism, control wire pulleys and control wire and cable conduit have employed laminated plastics.

Other applications arising from lightness are meter vanes ; float balls for valve control which can often be made smaller for the same buoyancy than metal ; cooling fan blades ; moving parts such as

pulleys and links of mechanisms which frequently change speed, where power saving and speedier operation due to lower inertia becomes important, as for example switch mechanisms and capstan lathe pulleys.

7.7. For Other Advantages.

The low heat conductivity is an advantage for control handles and levers.

Thin shells or webs would often be possible on metal parts without the ordinary working stresses becoming excessive, but have the disadvantage that they are easily dented or distorted in handling. Laminated plastics often have sufficient resilience to resist damage in this way and if necessary, moreover, these thin portions can be thickened and still leave some advantage in lightness. A float ball has been successfully produced as a laminated moulding 1/16 in. thick. A copper float of the same weight and displacement would have to be about ·0095 in. thick and so would quite easily be dented even if manufacturing difficulties could be overcome. If 1/64 in. were considered a minimum thickness for the copper the weight would be increased 60% so that considerably larger diameter would be necessary to give the same buoyancy. Metal parts must often be made thicker than indicated by stress calculations. Thus a 3-in. cylinder of brass designed to burst at an internal pressure of 150 lbs./sq. in. would only need to be about ·005 in. thick, but would obviously have to be made many times thicker to become manageable. A laminated plastics tube for the purpose need probably be made no thicker than the brass would have to be, and would be much lighter. Many similar cases arise in practise.

While the material costs of laminated plastics size for size is greater than steel and of a similar order to brass, the elimination or simplification of operations such as machining, painting, etc., may often give an advantage in final cost, apart from technical advantages.

8. SOME SPECIAL DESIGN PROBLEMS.

8.1. Tolerances.

Machining tolerances of ·002 in. (*e.g.* limits $\pm$ ·001 in.) can be obtained on moderate dimensions. Finer limits can sometimes be obtained, but add considerably to the difficulty and cost of production. They are rarely necessary due to the much greater extension possible without fracture compared with steel, which eliminates the need for accurate fits since interferences may be large. Moreover the small variations in dimensions possible due to swelling reduce the value of ultra-close limits.

On the other hand wider limits considerably simplify manufacture. Tubes 3 in. dia. for example, can be made without turning operations to internal limits of $\pm$ ·005 in. and external limits of $\pm$ ·010 in. with

varnish or $\pm \cdot 003$ in. and $\pm \cdot 005$ in. respectively without varnish. Mouldings require limits of a similar order on account of shrinkage in the tool if subsequent machining is to be avoided. The thickness of sheet is pre-determined by the number of pieces of paper or fabric employed in its manufacture and a considerable variation cannot be avoided due to irregular thickness of paper or fabric and fluctuations in resin hardness. Thus a ½ in. sheet of laminated paper may vary by $\pm \cdot 012$ in. and fabric by $\pm \cdot 013$ in. to $\pm \cdot 018$ in. depending on the grade. Greater accuracy can be obtained by subsequently grinding one face or both faces, but this destroys the natural surface finish.

For these reasons, it assists greatly in producing an economic product to specify the widest possible tolerances, and not to be governed too closely by the tolerances customary with metals.

8.2. Swelling.

Change in dimensions when immersed in water may be of the order of ·002 in. per inch. If the article becomes damp but not saturated the change will be less. Provision for this must be made in the case of bearings and pump rings by designing with adequate clearances. No considerable stress is needed, however, to resist or annul the swelling.

8.3. Expansion.

Where laminated fabric or paper is used in conjunction with metal, the question of stresses due to relative expansion arises. The coefficients of expansion of different grades vary around a figure of ·00002 per °C. along the layers (the direction of greatest practical significance), so that the ultimate expansion differs little from that of brass or steel. The stresses are therefore small, and in any case have little significance in comparison with those arising because the extension or contraction of laminated plastics lags behind that of the metal, the lower conductivity of the plastics preventing it from changing its temperature so quickly. The Young's Modulus is low, so that despite this the plastics material can accommodate itself to the metal without excessive stresses. Thus the stress involved in preventing completely the expansion of laminated plastics within a temperature range of 200°F. is about 3,000 lbs. per sq. in. It has long been established practise to fix metal flanges to laminated plastics articles with a synthetic cement in such a way that the complete article can stand the same range of temperature as the plastics material itself.

9. THE FUTURE OF LAMINATED PLASTICS.

Laminated plastics do not claim attention as substitutes for metals and other materials in the sense that they justify use where these

offer simple and satisfactory solutions of a problem. War-time shortages have made such substitutions necessary in some cases, but in many more laminated plastics have been used on account of one or more distinct advantages. Their use in the future is only justified if they solve particular problems with which the engineer is faced more satisfactorily and economically. There is no doubt that a large number of cases are likely to arise where laminated plastics is the best material for the job. That, and that only, is their justification.

10. CONCLUSION.

In conclusion I desire to acknowledge my indebtedness to the management of the Bushing Company for authority to publish this paper, and to Mr. W. J. Brown of that company for the inclusion of some sections and diagrams from his presidential address on "Laminated Plastics" to the North-East Section of the Institute of the Plastics Industry.

LIST OF ILLUSTRATIONS.

DISCUSSION

Q. Mr. Bennett: Wanted to know more about the absorption of plastics; he understood that most plastics absorbed water, and wanted to know what happens when it freezes or the temperature is quite a bit below Zero.

Also regarding the purification of water by synthetic resins, he understood there has been some recent experiment whereby it was possible to purify sea water, but thought he would like a little more information on this point, and wanted to know whether it has been developed sufficiently to use purification of water for boilers, etc.

Concerning power factor, he would like to know how it was applied to plastics.

A. Water absorption varies with the size of the specimen. It is naturally a surface effect, and roughly amounts to something like 1% due to immersion for 24 hours. As far as had been possible to determine, the freezing of water has no effect whatever.

Concerning the second question, Mr. Cook had no information upon the purification of water by resins.

In answer to the third question he said that power factor applied to insulation simply indicates the amount of power absorbed by the insulation due to the current which passes through it divided by the voltage and by the current; in other words, it is the angle between the current in the insulator and the voltage. In a perfect insulator the power factor would be zero, but usually with laminated paper of the electrical type it would be of the order of about 0·4% at normal temperature.

Q. Mr. Alder: Wanted to know if plastics were used frequently for sterns of ships, petrol tanks, air receivers, etc.

A. Confirmed that plastics have been used very successfully for stern tube bearings. The extension of their use is still being very seriously considered, and many tests are being made with that particular aim in view. With regard to petrol tanks, etc., he said these were rather too large to produce by pressure moulding. He thought these had been made in quite a number of cases, but that not a great deal has yet been done in this country.

Q. Mr. Burt: Wanted to know what particular lubrication is required for bearings.

A. Lubrication as lubrication is hardly necessary, but it is necessary to remove the heat produced due to the friction.

Q. Mr. Rowland: Have thermoplastic resins been used with laminated materials successfully?

A. The high impact strength of laminated materials derives from the fabric rather than from the resin, and in the case of laminated

materials thermoplastic resins do not materially alter the impact strength in cases where they have been tried, but where laminated materials have been built up from thermoplastic resins they have been used for electrical purposes rather than mechanical. The use of thermoplastic resins with laminated materials has not yet gone far, but there are several possibilities in that direction which have to be investigated.

Q. MR. EMMONS : Wanted some more information concerning the formation of the chain compound, and what determined its length.

A. Confirmed that the main factor which determines the length of the chain is usually heat.

Q. MR. KNIGHT : Could Mr. Cook give him some idea of the hardness demanded of the cutting tools for this material.

A. Machining is not difficult providing one or two precautions are taken, and the best tools usually are the tungsten carbide tipped tools. There is a tendency to clog the tools, and for satisfactory machining a really sharp edge has to be maintained, because it is very disastrous to tear away the material rather than cut it. It is most satisfactory to use tungsten carbide tipped tools and machine dry. A lubricant can be used, but it may in certain cases be detrimental to the application ; for example if it is an electrical insulator, grease absorption is undesirable ; it is very difficult to varnish if any grease gets on the surface.

Q. MEMBER : Mentioned that in civil industries, notably paper industries, also laminated plastics industries, a great deal of use was necessary of long press rolls with very fine finish, and which also must have absolute minimum static effect, and wanted to know if any of the laminated plastics could be put to that purpose instead of using cast iron, etc., the point being that this would introduce a much lighter weight.

A. Where rolls are required to be maintained parallel within accurate limits, laminated plastics cannot be very successfully applied because there is a tendency for a long roll to sag under the load. Where a high degree of accuracy is not necessary, great advantages can be obtained by the use of laminated fabric due to its lower weight, and rolls of this description have been used in various parts of cotton machinery and woollen machinery quite successfully.

Q. MEMBER : Are plastics used frequently in the making of the brakes of cars, etc. ?

A. Yes.

Q. MR. IRONS : Wanted to know a little more about the dyeing of plastics, *i.e.*, for domestic purposes, and would certain dyes have any effect on the organic plastic.

A. There is usually a very free choice of dyes, and the author had never met any case where the organic plastic has been affected.

Q. MR. CRANTEON : Wanted to know the resistance of various resins.

A. Resins are usually very resistant to acids, but not to alkalis in every case. He went on to say that the effect on laminated materials is greater as the resistance of the fibre is not as good as the resin itself. Most weak acids and nearly all organic acids have no effect, but oxidizing acids such as Nitric destroy the cellulose.

Q. MR. BENNETT : To what limit can you make the threads ?

A. Threads can be made over a pretty considerable range, and can be made either by machining or in some cases by moulding. 26 T.P.I. can be cut very successfully, and cases are known where 32 T.P.I. have been produced. With fabric it is rather more difficult to get such a fine thread because at such fine limits bits of fabric come to the surface which would rather mar the thread. There is no difficulty in getting fine threads if the job is done slowly, and not so quickly as a thread in metal. At all costs avoid tearing the material rather than cutting it. Attention was drawn to the fact that the production of threads produced no difficulty providing the right material is used. Some grades would not look at a screw thread.

Q. MR. SMITH : Have bevel gears been successfully cut from laminated plastics ?

A. Bevel gears must be moulded specially, with the laminations following the teeth and must definitely not be cut from sheet.

Q. MEMBER : Wanted information concerning the power factor of laminated paper and laminated fabric.

A. The power factor of laminated paper is definitely better than laminated fabric, the power factor of laminated paper being somewhere around the order of 0.5%, whereas fabric may be as high as 50%.

This ended the discussion amidst hearty applause, and Mr. Bennett, Section Chairman, said that all present must agree that a very fine lecture had been presented, and he then asked Mr. Daggliesh and Mr. Kench to propose a vote of thanks to Mr. Cook and his colleague who had so kindly come along to help.

Mr. Daggliesh, a visitor, stated that he agreed with Mr. Bennett that it had been a most interesting evening, and expressed his appreciation of the excellent slides, and remarked that it was most gratifying to see such a splendid attendance, and said he realized that the Lecturer and his colleague had travelled a long distance to get to the Meeting under very difficult circumstances, and presented his best wishes for better conditions on the return journey of

600 miles. He then proposed a hearty vote of thanks to Mr. Cook and his colleague for the most able lecture.

Mr. Kench seconded the vote of thanks, endorsing all that the proposer had stated, and said it was most gratifying to know that plastics had been developed so extensively in this country. The Chairman then put the vote to the meeting, and the same was heartily received in the usual manner.

INSTITUTION NOTES

December, 1945

ANNUAL GENERAL MEETING.

Official Notice.

NOTICE IS HEREBY GIVEN that the Annual General Meeting of the Institution will be held on Friday, 14th December, 1945, at the Institution of Civil Engineers, Great George Street, London, S.W.1, at 10-30 a.m.

Agenda :

1. Notice convening Meeting.
2. Minutes of previous Annual General Meeting.
3. Election of Members of Council.
4. Presidential Address.
5. Annual Report of the Council.—Research.—Balance Sheet.
6. Election of Auditors, 1945-46.
7. Votes of thanks.

BY ORDER OF THE COUNCIL,

C. B. THORNE,

Director-General Secretary.

December Meetings.

3rd Coventry Graduate Section. Joint meeting with the Graduate Sections of Inst. of Mechanical Engineers, Inst. of Automobile Engineers and Royal Aeronautical Society, when Sir A. H. Roy Fedden will speak on his "Recent Visit to Germany for the Ministry of Aircraft Production," at the Technical College, Coventy, Room A5, at 6-45 p.m.

3rd Yorkshire Section. A lecture will be given by A. McLeod, M.I.P.E., on "The Technical Press as an Aid to the Production Engineer" at the Hotel Metropole, Leeds, at 7-00 p.m.

4th Wolverhampton Graduate Section. A lecture will be given by G. H. Parlor, Esq., on "The Rubber Bolster Press and Its Applications," at the Wolverhampton and Staffordshire Technical College, Wolverhampton, at 7-00 p.m. This lecture will be illustrated by slides.

6th Glasgow Section. Discussion evening on "Machining Problems." Problems will be tabled by Messrs. W. Buchanan, J. McFarlane and I. M. Lyon, at the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, at 7-15 p.m.

December Meetings.—*cont.*

7th Leicester Section. A joint meeting with the Leicester Association of Engineers, when R. M. Evans, Esq., will read a paper on "Making a Typewriter," at the Leicester College of Technology, Leicester, at 7-00 p.m. This lecture will be illustrated by Lantern Slides.

7th Western Section. Annual Dinner, Grand Hotel, Bristol, 1.

8th Manchester Graduate Section. Visit to Metropolitan Vickers Electr. Co. Ltd., Trafford Park, Manchester.

8th North-Eastern Section. Fourth Annual Dinner, to be held in the County Hotel, Newcastle-on-Tyne, at 6-30 p.m. for 7-00 p.m.

8th North-Eastern Graduate Section. Works Visit to Messrs. Bushing Co. Ltd., Team Valley Trading Estate, Gateshead.

11th Luton and District Section. A lecture will be given by H. Fairbairn, Esq., on "Die Casting," at the Small Assembly Room, Town Hall, Luton, at 7-00 p.m.

12th Preston Section. A lecture will be given by V. W. Pilkington, Esq., on "Impressions in America," at the Municipal Technical College, Manchester Rd., Bolton, at 7-15 p.m.

12th Wolverhampton Section. A lecture will be given by J. H. Paterson, D.Sc., on "Replacement of Castings by Welded Fabrication," at the Wolverhampton and Staffordshire Technical College, at 6-30 p.m.

13th Leicester Section. A lecture will be given by F. J. Everest, Esq., on "Developments in Gear Cutting and Finishing Processes," at the Leicester College of Technology, at 7-00 p.m. This lecture will be illustrated by Lantern Slides.

13th South Wales and Monmouthshire Section. A lecture will be given by Lt.-Col. C. G. Chantrill, on "Functional Training and Selection in Industry," at the South Wales Institute of Engineers, Park Place, Cardiff, at 6-30 p.m.

13th London Section. A lecture will be given by A. Craig McDonald, B.Sc., on "Some Modern Methods of Heat Treatment," at Lecture Hall, Inst. of Mechanical Engineers, Storey's Gate, St. James' Park, S.W.1, at 6-30 p.m.

15th Yorkshire Graduate Section. A lecture will be given by R. W. Whittle, M.I.P.E., M.I.Loco.E., A.M.I.Mech.E., on "Rehabilitation into Industry," at the Great Northern Hotel, Leeds, at 2-30 p.m.

December Meetings.—*cont.*

15th Shrewsbury Sub-Section. A lecture will be given by A. W. Wallbank, Esq., on "Protective Metal Finishes," at Shrewsbury Technical College, at 3-00 p.m.

17th Derby Sub-Section. A lecture will be given by T. B. Maddison, A.M.I.P.E., on "Production Methods in Railway Workshops," at the School of Art, Green Lane, Derby, at 6-30 p.m.

17th Halifax Section. A lecture will be given by Dr. D. F. Galloway, B.Sc., Director of Research I.P.E., on "Technical Design on Machine Tools," at the Technical College, Halifax, at 7-00 p.m.

19th Sheffield Section. A lecture will be given by W. Neville, Esq., on "Shot Peening," at the Royal Victoria Station Hotel, Sheffield, at 6-30 p.m.

19th Birmingham Section. A lecture will be given by A. J. Nicol, Esq., on "Personnel Management as a Service to Production," at the James Watt Memorial Hall, at 7-00 p.m.

19th Wolverhampton Section. A lecture will be given on "Unification of Screw Threads between Great Britain, America and Canada," at the County Technical College, Wednesbury, at 6-30 p.m. Speakers: Sir Anthony Bowlby, Bt. and Mr. P. Elson.

20th Glasgow Section. A lecture will be given by R. B. C. Douglas, M.B.E., on "The Training and Employment of the Disabled," at the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, at 7-15 p.m.

20th Birmingham Section. Christmas Dinner and Concert at the Imperial Hotel, Temple Street, at 7-00 p.m.

21st Eastern Counties Section. A lecture will be given by R. K. Mawson, Esq., of the Factory Dept., Ministry of Labour, on "Accident Prevention"; with special reference to Engineering Machinery, at the Lecture Hall, Electric House, Ipswich, at 7-15 p.m.

Wolverhampton Graduate Section. Works visit to Wellman Smith Owen Eng. Corporation, Ltd., Darlaston. Date not fixed yet.

January Meetings.

5th North-Eastern Graduate Section. Social Evening at the Newcastle and Gateshead Gas Co.'s Demonstration Theatre, St. John Street, Newcastle-on-Tyne, at 6-30 p.m.

January Meetings.—*cont.*

7th Yorkshire Section. A lecture will be given by E. W. Forster, B.Sc., on "Electronics in Production Engineering," at the Hotel Metropole, Leeds, at 7-00 p.m.

7th Coventry Graduate Section. A lecture will be given by R. R. Brittain, Grad. I.P.E., on "Designing for Efficient Production," at the Technical College, Coventry, Room A5, at 6-45 p.m.

8th Luton and District Section. Film Show on Grinding—Universal Grinding Wheel Co.—at the Small Assembly Room, Town Hall, Luton, at 7-00 p.m.

8th Birmingham Graduate Section. A Discussion Meeting will be held at the James Watt Memorial Hall, Great Charles Street, Birmingham, at 7-15 p.m. Members willing to give a short paper please contact the Hon. Secretary.

9th Manchester Graduate Section. A lecture will be given by J. W. Gardom, Esq., on "Modern Foundry Practice," at the College of Technology, Manchester, at 7-15 p.m.

11th Leicester and District Section. Joint Meeting with the Institute of Economic Engineers when a lecture will be given by W. T. Laxton-Roberts, M.I.Ec.E., A.M.I.P.E., on "Time Study," at the Leicester College of Technology, Leicester, at 7-00 p.m. This lecture will be illustrated by lantern slides.

12th Yorkshire Graduate Section. "Short Papers" by Graduates and Students at the Great Northern Hotel, Leeds, at 2-30 p.m.

15th Wolverhampton Graduate Section. A lecture will be given by D. W. Goodreid, Esq., on "Application of Hydraulic Power to Machine Tools," at Walsall Technical College. Full details to follow.

16th Sheffield Section. A lecture will be given by C. J. Dadswell, Ph.D., M.I.M.E., on "Mechanical Production in a Modern Steel Foundry," at The Royal Victoria Station Hotel, Sheffield, at 6-30 p.m.

16th Preston Section. A lecture will be given by T. P. N. Burness, M.I.P.E., on "Modern Methods of Production of Machine Tools," at the Canteen of British Northrop Loom Co. Ltd., Daisyfield, Blackburn, at 7-15 p.m.

17th South Wales and Monmouthshire Section. A lecture will be given by Prof. H. W. Swift, M.A., B.Sc., of Sheffield University, on "Deep Drawing of Metals," at the South Wales Institute of Engineers, Park Place, Cardiff, at 6-30 p.m.

January Meetings.—*cont.*

17th London Section. A lecture will be given by Dr. J. D. Jevons on "Deep Drawing and Pressing" at the Institution of Mechanical Engineers, Lecture Hall, Storey's Gate, St. James's Park, London, S.W.1, at 6-30 p.m.

17th Glasgow Section. A lecture will be given by F. W. Hopkinson, A.M.I.Ae.E., on "The Maintenance of Aircraft," at the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, at 7-15 p.m.

17th Manchester Section. A lecture will be given by K. G. Fenelon, M.A., Ph.D., on "The Foreman—his Training and Function in Industry," at the College of Technology, Manchester, at 7-15 p.m.

18th Coventry Section. A lecture will be given by Dr. C. M. Blow on "A Review of the Development of Rubber-to-Metal Bonding" at Coventry Technical College, Room A5, at 6-45 p.m.

18th Eastern Counties Section. Discussion on "Unification of Screw Threads." Details to follow.

18th Western Section. A lecture will be given by L. E. Broome, A.M.I.P.E., on "Personnel Management," at The Grand Hotel, Broad Street, Bristol 1, at 6-45 p.m.

18th Manchester Section. A lecture will be given by K. G. Fenelon, M.A., Ph.D., on "The Foreman—his Training and Function in Industry," at the Mechanics Institute, Crewe, at 7-15 p.m.

19th Manchester Section. A lecture will be given by K. G. Fenelon, M.A., Ph.D., on "The Foreman—his Training and Function in Industry," at Liverpool University, Brownlow Hill, at 2-30 p.m.

19th Nottingham Section. A lecture will be given by E. G. West, Ph.D., B.Sc., on "The Effects of Development in Light Alloys on Future Design," at the Demonstration Theatre, Corporation Gas Showrooms, Lower Parliament Street, Nottingham, at 2-30 p.m.

21st Derby Sub-Section. A lecture will be given by S. C. Roberts, F.C.W.A., M.I.I.A., on "Costing as Applied to Production," at the School of Art, Green Lane, Derby, at 6-30 p.m.

21st Halifax Section. A lecture will be given at the Technical College, Huddersfield, on "Automatic Electrical Control Gear." Full details to follow.

January Meetings.—*cont.*

25th Lincoln Sub-Section. A lecture on "Broaching" will be given at the Lincoln Technical College at 6-30 p.m. Full details to follow.

26th Yorkshire Graduate Section. Visit to Courtaulds, Ltd., Bradford, Textile Manufacturers, at 2-30 p.m.

December Committee Meetings.

4th Education Committee at 10-30 a.m. at the Imperial Hotel, Birmingham.

4th Membership Committee at 12-30 p.m. at the Imperial Hotel, Birmingham.

17th Research Committee at 11-45 a.m. at Loughborough College, Loughborough, Leics.

21st Finance and General Purposes Committee at 2-30 p.m. at the TEMPORARY Committee Room, 36, Portman Square, London, W.1.

Technical and Publications Committee meet every Wednesday at 5-30 p.m. at the TEMPORARY Committee Room, 36, Portman Square, London, W.1.

COUNCIL MEETING. The next meeting of the Council will be held on Friday, 14th December, 1945, at 11-00 a.m. at the Institution of Civil Engineers, Gt. George Street, London, S.W.1.

Until further notice the meetings of the Finance and General Purposes Committee, the Technical and Publications Committee and the London Section Committee will be held in the TEMPORARY Committee Room at 36, Portman Square, London, W.1. All correspondence is still to be addressed to No. 10, Seymour Street, London, W.1.

SOUTHERN SECTION. The Southern Area Section held an interesting Educational Tour of Portsmouth Dockyard and Workshops on Tuesday, 30th October. This visit was made possible by the kind permission of Vice-Admiral M. L. Clarke, C.B., D.S.C. The party much appreciated the attention and explanation given by the Dockyard Staff who acted as guides.

Personal.

Mr. S. Worne, M.I.P.E., has left the Chesterfield Tube Co., Ltd., and has joined The Wellman Smith Owen Engineering Corporation Ltd. in the capacity of Manager of the Furnace Contracts Department.

Obituary.

We deeply regret to record the death of Mr. J. Russel Gimson, M.I.P.E., Leicester Section, Managing Director of Messrs. Gimson & Co. (Leicester) Ltd.

Some Notes on Employment of the Disabled, by K. G. Fenelon, M.A., Ph.D.

Modern industry, on account of its highly-developed specialization, offers many opportunities for the economic employment of the disabled. First-class all-round physique is only required in a limited number of jobs, and a man is not at a disadvantage in wage-earning capacity if he can be fitted to a job within the limits of his physical abilities. In a recent report of the U.S. Department of Labour, it is recorded that the Ford Motor Co. employed 11,000 persons with some form of physical defect. The Company stated that all their handicapped workers gave full value for the wages received, and that the tasks were carried out with absolutely no allowances or special considerations. "Our real assistance to them has been merely the discovery of tasks which would develop their usefulness." In our own country, labour shortages during the war led many firms to employ disabled persons with results that greatly exceeded expectations. The employment of disabled persons is now shortly to become a statutory obligation. Under the Disabled Persons (Employment) Act, 1944, which implemented the main recommendations of the Tomlinson Committee, all employers of 20 or more persons will be required in effect to employ a quota of workers from a Register of Disabled Persons. This Register was opened on September 25th last, and other sections of the Act will come into operation shortly. Managements therefore should plan now for the satisfactory placement of their quota of disabled workers. Works managers, personnel managers and foremen can materially aid this by careful analysis of the various jobs in the factory or shop, so as to determine which can be filled by persons with some physical disability. Plant, processes and tools can often be adapted to the special needs of disabled persons. The aim should be to place each disabled person in a job where he can do the most skilled work of which he is capable and which, moreover, he can fill on his merits as a worker in ordinary competition with other workers.

IMPORTANT !

In order that the Journal can be despatched on time copy must reach the Head Office of the Institution by not later than 40 days prior to the date of issue, which will be the first of each month.

Issue of Journal to New Members.

Owing to the fact that output has to be adjusted to meet requirements, and in order to avoid carrying heavy stocks, it has been decided that the Journal will only be issued to new Members from the date they join the Institution.

Books Received.

Safety of Machine Tools and Other Plants issued by the Factory Dept., Ministry of Labour and National Service.

Truncated Whitworth Form Screw Threads published by the British Standards Institution.

Canadian Trade Index published by the Canadian Manufacturers' Association, Inc.

Time and Motion Economy for Supervisors, by James D. Shevlin. Published by The National Foremen's Institute, Inc., Deep River, Conn., U.S.A.

The book presents the principles of Motion Economy and Time Study to the Foreman and man in the shop in a very simple manner. It also has the advantage of being a definite link with the newly-introduced method of T.W.I. job methods and job instruction training.

It wisely keeps clear of looking on time and motion study as super-specialized functions by discussing them in common terms, and completely eliminating the complicated signs, symbols and hieroglyphics connected with therbligs and chronocycles. While it may be felt that it introduces yet another symbol—termed OTIS—this is actually done for simplicity, for the foreman to check effectively under the headings of O for Operation, T for Transportation, I for Inspection and S for Storage.

Most production engineers now realize that the efficiency of production is not only tied up with the technique of process layouts and tooling, but also with work flow and handling methods.

This simple book, specifically edited for the benefit of foremen, should be very useful in selling the application of Time Study and Motion Study to improve the production efficiency of his department as a whole.

B. H. D.

Research Department: Production Engineering Abstracts

(*Prepared by the Research Department.*)

NOTE.—*The Addresses of the publications referred to in these Abstracts may be obtained on application to the Research Department, Loughborough College, Loughborough. Readers applying for information regarding any abstract should give full particulars printed at the head of that abstract including the name and date of the periodical.*

HEAT TREATMENT.

Toughening Tank-wheel Rims by High-frequency Induction. (*Machinery, 11th October*, 1945, *Vol.* 67, *No.* 1722, *p.* 393, 7 *figs.*)

The Tocco method was adopted to harden alloy steel wheel rims. The main high-frequency circuit is shown schematically, and the operating cycle is described.

The Influence of Natural Convection on Radiant "Infra-Red" Heating, by J. B. Carne. (*Sheet Metal Industries, October*, 1945, *Vol.* 22, *No.* 222, *p.* 1757, 12 *figs.*)

The magnitude of the convection loss from the heated object relative to that of the radiation absorbed by it is all-important. A certain minimum temperature of the object is essential. The attainable temperature is a prime characteristic of an oven and attention is given to the physical factors on which this depends. The calculation of equilibrium temperature from heat transfer data, and experimental results are discussed in detail. An important conclusion is that a prime factor in the choice between convection and "infra-red" ovens is curvature of the object of treatment.

EMPLOYEES, APPRENTICES.

Selection Tests in Industry, by Alec Rodger. (*Industrial Welfare, September-October*, 1945, *Vol. XXVII*, *No.* 302, *p.* 142.)

Selection tests are widely used, but they are only part of the whole selection procedure. Such tests have proved valuable in the Services. Intelligence tests are the most useful and other kinds are of less general importance. The core of selection procedure should still be the interview. Tests, together with questionnaires, should be looked upon as aids to the interview. Few people object to tests, but they must be allowed for. Unless tests are supervised by properly qualified personnel, serious difficulties will arise. Practical suggestions on the introduction of a scheme are given.

Interrupted Apprenticeships. (*Production and Engineering Bulletin, Sept.-Oct.*, 1945, *Vol.* 4, *No.* 33, *p.* 365.)

The Government scheme to help men and women to complete their training is described. Provision is made for reduction in unexpired time and three forms of allowance are payable.

FOUNDRY.

Permanent-Mould Castings, by L. F. Swoboda. (*Aircraft Production, October*, 1945, *Vol. VII, No.* 84, *p.* 499.)

A survey of the advantages of the process, and cost and design considerations, is given for light metal castings. Such castings have many advantages over other cast products, including better metallurgical quality. Their dimensional accuracy is between that of sand and die castings. The properties of some light-metal permanent-mould alloys are detailed. Design considerations for both mould and casting are discussed, and a chart of commercial tolerances is given.

Applications to Meehanite to Die-casting Equipment, by H. K. and L. C. Barton. (*Machinery*, 27*th September*, 1945, *Vol.* 67, *No.* 1720, *p.* 356, 8 *figs.*)

The advantages of Meehanite for casting equipment requiring resistance to temperature and pressure effects are enumerated, and applications to pots, goose-necks, etc., are described.

HEATING VENTILATION.

Thermionic Valve Control of Heating and Ventilation Installations, by S. B. Jackson. (*Machinery Lloyd*, 29*th September*, 1945, *Vol. XVII, No.* 20, *p.* 64, 9 *figs.*)

Valve and photo-cell applications of temperature, humidity and dew-point control are described, and circuit diagrams are given. Infinitely variable control of temperature by electronically-operated voltage regulators is possible. Electronic precipitators are available for dust precipitation.

MACHINE ELEMENTS.

The Design of Accurate Live Tailstock Rams and Running Centres, by F. M. Birch and J. Lunzer. (*Machinery*, 11*th October*, 1945, *Vol.* 67, *No.* 1722, *p.* 405, 10 *figs.*)

The principles of good design for various classes of work, and the proper selection of anti-friction bearings for different applications are set forth. Requirements include: support near the centre, journal support close to the centre, no play under all conditions, positive thrust location, sufficient rigidity, alignment, truth, and efficient sealing. The effect of each requirement on design is discussed in detail and in relation to actual designs.

Design of Taper and Parallel-shank Running Centres, by F. M. Birch and J. Lunzer. (*Machinery*, 18*th October*, 1945, *Vol.* 67, *No.* 1723, *p.* 435, 17 *figs.*)

The design of running centres is discussed for: (1) General work to commercial limits. (2) High-production and heavy work to commercial limits and general form-tool work on capstans. (3) Light work, at high speed, to fine limits. (4) High-production and heavy work with interrupted cuts, to fine limits, using tipped tools. (5) Accurate, heavy, or high-production and form-tool work on capstans and turrets. (6) Accurate, heavy, or high-production and form-tool work to fine limits. Seventeen actual designs are critically examined and their suitability for the different types of work considered.

A New Bearing for Machine-tool Spindles, by P. E. Burger. (*Machinery, 27th September*, 1945, *Vol.* 67, *No.* 1720, *p.* 350, 2 *figs.*)

For high speeds the main objections to the use of a plain bearing are the definite clearance to be allowed, and the precision required in shaft surface finish. A simple type of sleeve bearing developed by the author is claimed to provide theoretical refinements of practical importance. This bearing consists of an outer shell, in which are supported in a resilient matrix, a number of bearing surface elements, divided in both radial and axial planes, each particular segment being completely isolated from the other. The resilient matrix is usually made from a suitable grade of synthetic rubber, impervious to oil, and resistant to temperature. The general construction compensates for spindle deformations. Different types are described, including one with carbon instead of bronze bearing faces.

MACHINING, MACHINE TOOLS.

Developments and Trends in American Industries—Metal Forming, Part 5. (*S*-7514, *U.S. Office of War Information.*)

Excerpts from various sources give a broad survey of important technological and scientific developments and trends in machining, machine tools and tooling in the United States in recent years. They cover the major aspects of this industry and suggest probable post-war developments.

Trouble Shooting Problems in Steel Machining, by J. H. Greenberg. (*Machine Shop Magazine, September*, 1945, *Vol.* 6, *No.* 9, *p.* 54.)

Machining troubles can be analysed in a systematic manner. A procedure to be followed is laid down, and a chart to facilitate its application is given, along with a more detailed review of the factors concerned.

Multiple Tapping of Magnesium and Aluminium. (*Machinery*, 11*th October*, 1945, *Vol.* 67, *No.* 1722, *p.* 399, 9 *figs.*)

It was general practice, both to rough and finish-tap the threaded holes in aircraft engine parts one at a time, and in many instances, to follow up with a hand tapping operation. It was ascertained that the tearing of threads in tapping magnesium and aluminium was mainly due to forcing the tap in cutting or in backing out. By using taps having the thread ground concentric with the tap body and shank, and by grinding the tap flutes with a hand wheel, the tearing of threads has been eliminated. To meet the specification of medium fits each tap spindle in multiple set-ups required its individual lead-screw. Diagrams show the method of flute grinding. A number of examples are given.

Cylindrical Grinding Speeds and Feeds. (*Machinery*, 4*th October*, 1945, *Vol.* 67, *No.* 1721, *p.* 380.)

The effect of speeds and feeds on wheel action, wheel stresses, etc., for different wheels are discussed.

Centreless Grinding of Screw Threads. (*Machinery*, 18*th October*, 1945, *Vol.* 67, *No.* 1723, *p.* 421, 6 *figs.*)

The method has been successfully applied on a commercial scale to the grinding of hardened socket set-screws from $\frac{1}{8}$ to $\frac{5}{8}$ inch in diameter, with pitches from 40 to 11 t.p.i. Thread diameters up to 5 inches and thread lengths up to 12 inches have also been successfully handled. The error in lead can be commercially

held to ·0005-inch in 1 inch. The pitch diameter is constant, and concentric with the outside diameter. The sides of the threads are remarkably smooth and straight compared with cut threads, and the angle of the thread is as accurate as the angle of the grooves in the crusher used for dressing the wheel. The rate of production of socket set-screws is approximately five times that usual for cut threads. The principles of centreless thread grinding are fully described, and details are given of the Landis centreless thread-grinding machine. Practical features of the crushing operation, the effect of grain size of wheel, etc., are discussed.

Efficient Polishing of Sintered Carbide Drawing Dies, by W. Trurnit. (*Industrial Diamond Review, October*, 1945, *Vol.* 5, *No.* 59, *p.* 221, 11 *figs.*)

The author describes a simple method for re-boring worn stones with available machinery, so that even unskilled operators can recondition the holes with great accuracy. Comments on this article by a wire drawer and a technical consultant are appended.

Compound-angle Holes and Surfaces, by N. P. Skinner and K. L. C. Legg. (*Machinery, 27th September*, 1945, *Vol.* 67, *No.* 1720, *p.* 345, 12 *figs.*)

Part 2. This part shows how compound-angle workpieces may be set up in the workshop.

Increasing Productive Machine Time, by E. P. DeGarmo. (*Mechanical Engineering*, (*U.S.A.*), *September*, 1945, *Vol.* 67, *No.* 9, *p.* 584, 2 *figs.*)

Plant facilities must be used efficiently for reducing overhead costs. Planning, scheduling, and tooling are very closely related to productive machine time, and their proper use is essential in obtaining low production costs.

Disposal of Surplus Government Machine Tools. (*Production and Engineering Bulletin, Sept.-Oct.*, 1945, *Vol.* 4, *No.* 33, *p.* 340.)

Notes on the working of this scheme and the present position.

CHIPLESS MACHINING.

Rolled Threads, by W. T. Taylor. (*Metals and Alloys, June*, 1945.)

This article describes methods for performing the calculations necessary in determining the blank diameters of screws that are to be thread rolled. It covers various materials, types of component, thread form and class of fit. Tables are given to assist in this work. It is claimed that rolled threads can be produced with greater accuracy than cut threads. Attention is given to taps with rolled threads, and a high-speed blank requires a greater blank diameter for a given size of thread than does a blank of carbon steel.

(*Communicated by Machine Shop Magazine.*)

MANUFACTURING METHODS.

Economic Time Study in the Machine Shop, by H. Watson. (*Machinery, 4th October*, 1945, *Vol.* 67, *No.* 1721, *p.* 375.)

This article discusses how time studies should be made and applied to the machine-shop, and the part that the foreman should play in general efficiency.

Motion Study, by James Gillespie. (*Industrial Welfare, September-October,* 1945, *Vol. XXVII, No.* 302, *p.* 154, 1 *fig.*)

Part 2. Fundamental principles and applications are discussed, including: the principles of effective whole pattern, principle of whole work pattern, work physical pattern and work psychological pattern; the principles of individual physical response and similar response; principles of motion harmony, individual rhythm, body member rhythm and task speed variation.

Precision Bolts and Studs. (*Automobile Engineer, August,* 1945, *Vol. XXXV, No.* 465, *p.* 313, 16 *figs.*)

The manufacturing methods employed by A. P. Newall & Co., Ltd., for Hitensile, Newalloy, Newallastic and Newall Hi-tem bolts and studs are fully described. Pickling is done with the submerged combustion system. Cold heading is used for the production of bolts up to ⅞-in. diameter × 6-in. long. The reduced portions of Newallastic bolts and studs are obtained by cold swaging, and the threads are rolled despite the high tensile properties of the Mn-Mo steel used. Centreless precision thread generating machines, which employ cylindrical dies, are most suitable. Heat treatment, control of quality, inspection, and nut manufacture are also described.

MEASURING METHODS, INSPECTION.

Statistical Quality Control, by J. M. Howell. (*Aircraft Production, October,* 1945, *Vol. VII, No.* 84, *p.* 475.)

Statistical quality control has two major phases: process control and quality assurance. For the latter two satisfactory methods of sampling inspection are in common usage. If procedure is strictly followed, sample sizes and acceptance numbers can be so chosen that the outgoing quality may be maintained at any predetermined level. Double sampling is frequently used as well as single sampling. Process control in control of manufacture and statistical methods, including the use of control charts, has proved very useful. Control limits may be easily calculated, and must be checked against desired specification limits. The process continues till a point exceeds limits, and appropriate action is taken. If a process is in statistical control, but the limits of the process are not within specification limits, either the process or the specifications must be changed. Control charts for measurements have been used to control the quality of machine parts, etc., but these are applicable to non-manufacturing applications, such as control of amount of overtime worked. Where measurements are impossible or uneconomical, a control chart for per cent. defective may be made on a go-no-go basis. A control chart for number of defects per unit may be used for large complex units, or at a given station in an assembly line. Other statistical techniques in industry include frequency distribution showing the number of parts having a given dimension. Departure from pattern indicates inconsistencies. The control of quality should be the responsibility of a division separate from engineering, tooling, production, inspection, and purchasing. The head should have considerable manufacturing experience and some knowledge of statistical methods. His assistant should be a competent statistician who has a little knowledge of manufacturing methods.

A Double-Sampling Inspection Scheme. (*Production and Engineering Bulletin, Sept.-Oct.,* 1945, *Vol.* 4, *No.* 33, *p.* 350.)

Sampling methods applied to a small aluminium component are of the Dodge-Romig Double Sampling type, in which two small samples are taken. If the number of defectives found in the first sample is not greater than a certain number

the batch may be accepted without further inspection, while if it exceeds another predetermined number 100 per cent. inspection is necessary. If an intermediate number of defectives is found in the first sample, then the second sample must be examined and the result combined with that of the first sample.

PLASTICS, POWDER METALLURGY.

Good Preforming and Preheating Methods Insure Satisfactory Moulding, by D. M. Buchanan. (*The Machinist*, *6th October*, 1945, *Vol.* 89, *No.* 26, *p.* 905, 5 *figs.*)

Selection of a preforming and preheating method is dependent on the variables of designs, moulding compositions and economics, and these factors are discussed. A " Trouble Shooting " chart for plastic mouldings is included.

Powder-metallurgy Production of Machine Parts. (*Machinery*, *27th September*, 1945, *Vol.* 67, *No.* 1720, *p.* 337, 9 *figs.*)

Powder metallurgy has effected tremendous savings of time and material in the manufacture of detail parts. A part requiring two hours to machine is made from powder in twenty-two seconds. Parts made include self-lubricating bearings, precision V-blocks, pump gears, height-gauge bases, micrometer frames, and ball-bearing separators. The four major steps in manufacture are: mixing the pure metal powders, briquetting, sintering the briquettes, and sizing in dies to meet dimension tolerances. Bearings are also impregnated with a non-gumming lubrication oil. Physical properties or powdered metal parts for various classes of duty are given. Sample products, and manufacturing methods, are described.

RESEARCH.

Studies on the Machinability of Carbon and Alloy Steels, by G. P. Witteman. (*Mechanical Engineering*, (*U.S.A.*), *September*, 1945, *Vol.* 67, *No.* 9, *p.* 575, 22 *figs.*)

This paper deals with the machinability of cold-finished bars on screw machines. Machinability is defined as that property of a material which affects the speed at which a given cut may be taken under otherwise identical conditions. Two means of evaluating machinability are: (1) short-time tests at relatively high speeds and feeds, which give tool breakdown rather than tool failure and which furnish the best comparisons in so far as tool materials are concerned, and (2) long-time tests at optimum speeds and feeds with tool failures predicated on finish and maintenance of tolerances as they pertain to the finished part. The latter is more accurate in evaluating the material being cut. A four-spindle automatic is used for testing steels. After reviewing past data it was decided to abandon the short-time test and adopt the long-time test, using saleable parts as test pieces. The relative machinability is based upon the number of pieces per hour and not upon cutting speed. Five essentials of machinability are proposed: (1) tool materials and tool design, (2) cutting speeds plus feeds, (3) cutting fluids, (4) finish and tolerances, and (5) condition of chips; and examples related to each are quoted. Special attention is given to determining quality from chips, and several cases are illustrated. Microscopic examination of specimens is also described. From the tests a table of suggested structures for alloy steels to suit turning, forming, drilling and broaching operations has been compiled.

SHOP MANAGEMENT.

Bonus Incentives, by Wm. Craig. (*Machine Shop Magazine, September*, 1945, *Vol.* 6, *No.* 9, *p.* 90.)

The general practice in heat-treatment shops of payment on a "tonnage" basis is considered unsatisfactory, and a scheme is developed for calculation of standard times, and illustrated by an example of a mixed batch of components. Individual piecework is considered unsuitable, and pool bonus is recommended.

STANDARDIZATION.

Points to be Considered in the Unification of Screw Threads, by Dr. G. Schlesinger. (*Machinery, October* 18*th*, 1945, *Vol.* 67, *No.* 1723, *p.* 431, 5 *figs.*)

The standardization of thread calls for the consideration of seven items: pitch, effective diameter, angle of profile, minor diameter, major diameter, position of the flanks to the axis, and truncation or rounding of crest and root. The fundamentals of present systems and of the proposed truncations for B.S.W.-to-U.S.S. interchangability are discussed in relation to these basic items. Relevant continental standards are included.

SURFACE, SURFACE TREATMENT.

Surface Roughness, by L. P. Tarasov. (*Industrial Diamond Review*, July, 1945, *Vol.* 5, *No.* 56, *p.* 162, 2 *figs.*)

The relationship of readings to actual surface profile was studied with the aid of taper sections. ᵇrms was compared with "predominant peak roughness" and "deepest maximum roughness" for different machining processes, and the resultant ratios discovered, varying from 3 to 23·1, are given.

The Surface Preparation of Certain Cold-Worked Steels by Pickling, by P. D. Liddiard. (*Sheet Metal Industries, October*, 1945, *Vol.* 22, *No.* 222, *p.* 1731, 8 *figs.*)

The objects of pickling are: to remove oxide films, carbon deposits, amorphous metal, and improve keying of the protective layer. With cold worked steels straight pickling may not give good results due to decomposition of the lubricant. These films may be treated by oxidation, decomposition by alkalies, or heat, by grinding or solution in an organic solvent. Treatment by oxidation is dealt with in detail. The use of a solution containing nitric and sulphuric acids is recommended as a satisfactory bath for the pickling of steel which has been cold-reduced, using lubricants which are not removed before heat treatment. Such "difficult" steels can be given a satisfactory surface in this way for subsequent coating by other metals, enamels, etc.

Corrosion Protection of Magnesium Alloys by Anodic Treatment, by W. E. Prytherch. (*Engineering Materials, October*, 1945, *Vol. III, No.* 8, *p.* 184.)

Anodically oxidized magnesium rapidly loses its coating by contact with water, and the oxide is soft and discontinuous. Electrolytes are usually those which produce chemically stable coatings containing, or capable of absorbing, chromates. Recent progress is described, including that dealing with corrosion by metallurgical means.

The Technique of Sheet Galvanizing by the Hot Dip Process, by Harold Edwards. (*Sheet Metal Industries, September,* 1945, *Vol.* 22, *No.* 221, *p.* 1546, 9 *figs.*)

Pickling equipment and practice, galvanizing equipment, including heating systems, and mechanical equipment.

Electropolishing of Stainless Steel. (*The Iron Age, 12th July,* 1945.)

A citric-sulphuric acid process for imparting a bright finish to stainless steel is described in this article. Finishing in this way is said to improve the corrosion-resisting properties of the metal. The electrolyte consists of 55-60 per cent. sulphuric acid and 20-30 per cent. water. Copper cathodes are used in lead-lined steel or wooden tanks and the process is carried out at 190°F. A reclaim rinse, a cold rinse and a hot rinse follow the treatment. Surface irregularities are not removed but a bright and pleasing effect is obtained and the process should be of especial value for components that do not lend themselves to polishing by the more usual methods.

(*Communicated by Machine Shop Magazine.*)

Paints, Varnishes and Enamels, by H. Silman. (*Sheet Metal Industries, October,* 1945, *Vol.* 22, *No.* 222, *p.* 1773, 1 *fig.*)

Part 8. Recent developments. Types of paints. Drying, linseed, stand, blown, tung and other oils. Natural resins, copals, resin, ester gums and shellac. Synthetic resins.

Shot-peening. (*Aircraft Production, October,* 1945, *Vol. VII, No.* 84, *p.* 478, 3 *figs.*)

If properly used, the results are an appreciable increase of resistance to plastic deformation in the outer layers and an increase in the tensile strength of the metal immediately below the surface. A longitudinal compressive stress is also set up in the shot-peened layer. This last effect is beneficial in increasing resistance to fatigue failure. If the part is subsequently subjected to stresses equal to or greater than the yield strength of the peened surface, the increase in strength may be lost. Chemical composition, size and shape of the shot are important factors in obtaining good results from the use of the shot-peening process. Shot-peening has been adopted for the treatment of aircraft-engine connecting-rods, and the carefully controlled technique is described.

TRANSPORT, TRANSPORT EQUIPMENT.

Despatch System Controls Delivery of Parts in Conveyorized Factory. (*The Machinist, 6th October,* 1945, *Vol.* 89, *No.* 26, *p.* 893, 2 *figs.*)

Part I. A conveyor is used to connect 12 machining departments, each of which also has a conveyor. Flow of parts through each production phase is systematically controlled to suit the schedule of the assembly department.

Band or Belt Conveyors. (*Production & Engineering Bulletin, August,* 1945, *Vol.* 4, *No.* 32, p. 301, 14 figs.)

This general article includes descriptions of special conveyors, which can resist abrasion or heat.

WELDING, CUTTING, ETC.

Layout of a Welding Shop, by T. Scott Glover. (*Transactions of The Institute of Welding, August*, 1945, *Vol.* 8, *No.* 3, *p.* 93, 18 *figs.*)

The author discusses the welding shop and plant layout from a general engineering point of view and then outlines a specific example drawing attention to the considerations involved and the reasons for the arrangement as carried out.

Oxy-Acetylene Pressure Welding. (*Machinery, 4th October*, 1945, *Vol.* 67, *No.* 1721, *p.* 365, 7 *figs.*)

In oxy-acetylene pressure welding the workpieces are joined while in the solid state without the addition of any molten metal. In steel, temperatures of 2,100 to 2,300°F. and pressures of 2,500 to 4,500 lb./sq. in. are applied to effect upsetting. The process is especially adaptable to high-carbon and alloy steels. Equipment and the correct operating procedure and precautions are described in some detail. Close mating and cleanliness of the work faces are essential. Torch-normalizing serves as an effective means of producing desired improvements in the properties of the joint. The most extensive application has been to railway rails and pipe lines, but the process is finding increasing application in factory production and various applications are given.

Industrial Application of Automatic Submerged Arc Welding, by R. R. Sillifant. (*Welding, September*, 1945, *Vol. XIII*, *No.* 8, *p.* 360, 11 *figs.*)

The outstanding characteristic of the flux used is that it permits the use of high welding currents without loss of stability, thus giving deep penetration at high welding speeds. The relationship to other methods of arc welding and the fundamentals of the process are outlined. Various types of machines have been designed for specific uses, and will weld material up to 2½ in. in thickness in one pass, utilizing A.C. welding currents up to 3,500 amps. These machines are described, with particular reference to pressure vessel welding in which a two-pass method is usual. With single pass welding external means of backing up are necessary, and four methods are indicated. With two-pass welding a portion of the plate thickness to be welded is used as backing for the first run, and typical mechanical test results on a Union-melt weld are given. Likely future developments are: applications to low alloy steels with a higher strength-to-weight ratio than present-day structural steels and certain non-ferrous metals, notably copper and aluminium; and improvement of equipment, rods, fluxes, and welding techniques.

Manual Welding Manipulators, by F. W. Sykes. (*Welding, August*, 1945, *Vol. XIII*, *No.* 7, *p.* 295, 9 *figs.*)

Their construction and application for small assemblies and other purposes are described.

Resistance Welding, by R. W. Ayers. (*Aircraft Production, September*, 1945, *Vol. VII*, *No.* 83, *p.* 446, 16 *figs.*)

Part II. Equipment for spot welding light alloy material: stitch and projection welding.

Spot-Welded Joints, by A. J. Hipperson. (*Welding, October*, 1945, *Vol. XIII*, *No.* 9, *p.* 397, 11 *figs.*)

The more important mechanical tests for spot-welded joints are discussed with reference to the significance of the numerical data obtained from them.

It is shown that standardization of test specimens is necessary if the results are to be sufficiently consistent and accurate for comparative purposes.

Flash-Butt Weld Quality, by W. Forbes Young. (*Welding, September*, 1945, *Vol. XIII, No.* 8, *p.* 348, 1 *fig.*)

Attention is drawn to the likeliest causes of faulty welding. When faults occur the units to be welded should be checked for material and size. Attention should then be directed to the machine. The clamping dies should be inspected for rigidity, alignment, and wear of the contact areas which conduct current and heat. Faulty travel of the moving head may be due to incorrect manual operation, or faulty adjustment of automatic setting gear.

The Copper Brazing of Steel Components, by R. F. Tylecote. (*Engineering Materials, October*, 1945, *Vol. III, No.* 8, *p.* 185.)

This is an efficient production process for the assembly of small parts, and its possibilities are outlined. Details are given of the process, including the necessary precautions for alloy steels.

Machine Flame Cutting, by R. J. Wolf and J. H. McKlueen. (*The Foundry, June*, 1945.)

This article deals with the removal of risers, heads, etc., from steel castings by the use of flame cutting machines. Numerous types of casting are illustrated and advice is given on the selection of nozzles for using oxygen and acetylene. The use of machines was developed to speed up production beyond that obtainable when hand torches were used.

(*Communicated by Machine Shop Magazine.*)

Under Water Cutting, by Edward T. Forey. (*Welding, September*, 1945, *Vol. XIII, No.* 8, *p.* 355, 3 *figs.*)

Applications of the Oxy-Hydrogen Process.

Hot Riveting, by R. Bushell. (*Welding, September*, 1945, *Vol. XIII, No.* 8, *p.* 344, 11 *figs.*)

Hot rivetting by the electrical upsetting process, may be adopted for upsetting rivet heads, attaching pins to plates, etc., and as an alternative method to electric arc welding, projection welding or brazing. The process, types of joint and preparation, and typical plant are described.

WELFARE.

Attachments for Artificial Arms. (*Production and Engineering Bulletin, Sept.-Oct.*, 1945, *Vol.* 4, *No.* 33, *p.* 369.)

An indication of the way in which fitments that replace the hands enable workers who have lost one or both arms to perform many industrial jobs.

WORKS AND PLANT.

Clearance of Factories. (*Production and Engineering Bulletin, Sept.-Oct.*, 1945 *Vol.* 4, *No.* 33, *p.* 338.)

Stores and material made surplus by the termination of war contracts must be removed with the least possible delay, so that the contractors' resources may be turned over rapidly to peace production. The procedure to be used is described.

The Choice of Converting Plant for Works Services, by T. H. Carr. (*Mechanical World*, 21*st September*, 1945, *Vol.* 118, *No.* 3064, *p.* 319.)

The choice between motor converter, rotary converter and rectifier is illustrated by comparative costs for a 750 k.w. unit.

INDEX TO ADVERTISEMENTS

As a war-time measure the advertisement section of this Journal is now published in two editions,* A *and* B. *Advertisers' announcements only appear in one edition each month, advertisements in edition* A *alternating with those in edition* B *the following month. This Index gives the page number and edition in which the advertisements appear for the current month.

The fact that goods made of raw materials in short supply owing to war conditions are advertised in " The Journal " should not be taken as an indication that they are necessarily available for export.

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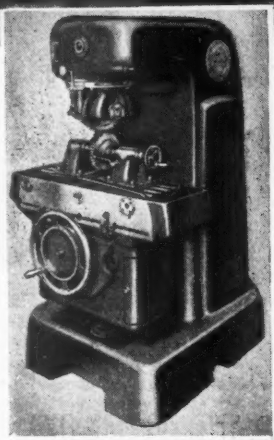

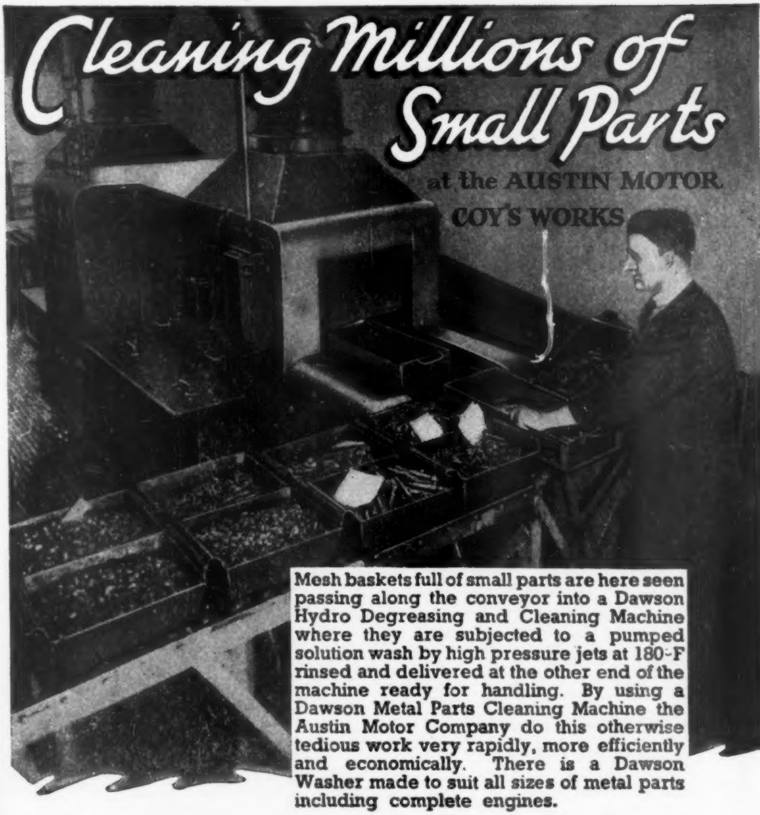
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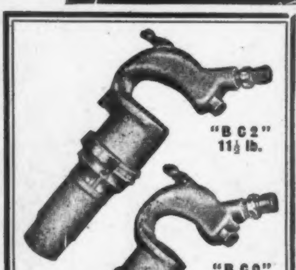

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